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Research Development

NOVEMBER 1987
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Laboratory management

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ABOUT THE COVER

Accurate three-dimensional graphic representation helps researchers to understand mathematical effects in the real world. For example, Versacad Corp.'s new enhancement for its "Design" software allows designers to make graphic representations of both algebraic and transcendental functions, including *n*th order polynomials and trigonometric, logarithmic, and exponential functions.

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Once mathematical functions are calculated, the computer displays the results as a series of triangular-meshed polygons. The software also takes advantage of 3-D software features, such as light-source color shading, hidden-line removal, and several display modes.

NEWS

43 **Fusion:** Test advances brighten outlook for fusion; infrared detector helps reduce laser accidents

44 **Instrumentation:** CCD technology brings more sensitivity to optical spectroscopy

45 **Physics:** Dept. of Energy is flooded with siting proposals for SSC

45 **Superconductivity:** 'U.S. must be aggressive in superconductor research'; British researchers advance superconducting thin films

46 **Science policy:** UK proposes sweeping changes in management of civilian R&D

48 **Technology export:** Flap over computer export reopens interagency rift

50 **Computers:** British system generates holograms with computer; test rig simulates wind loads on buildings

52 **Awards:** Laboratory of Year competition begins; *R&D 100* entry forms are available

Special Report—Space

57 Report says NASA will need more than the shuttle to build the space station; ESA is ready to press home its launch advantage; NASA again starts up its space tug development program; novel use of shuttle fuel tanks explored; study to define Mars rover vehicle configuration; funding issues ground UK space program

ARTICLES

66 **Don't drop the ball—or your new product:** Robert Szakonyi, George Washington Univ.; transfer of technology from R&D to marketing and manufacturing requires thought and planning.

72 **'Dominant science does not mean dominant product':** Ralph E. Gomory, IBM Corp.; understanding the manufacturing-development process is the key to industrial leadership.

78 **Your new laboratory may have an old shell:** Alan Kaplan, Haines Lundberg Waehler; you'll have to do your research and engineering homework before you decide to commit resources to your lab in an old building.

86 **How does your photopolymer cure?** Leonard C. Thomas, DuPont Co.; a differential photocalorimeter can determine properties of light-sensitive polymers and chemicals.

93 **Water vapor need not drive you mad:** Philip M. Danielson, Danielson Assoc. Inc.; basic understanding and simple procedures will remove water contamination from vacuum systems.

ABP BPA ABC

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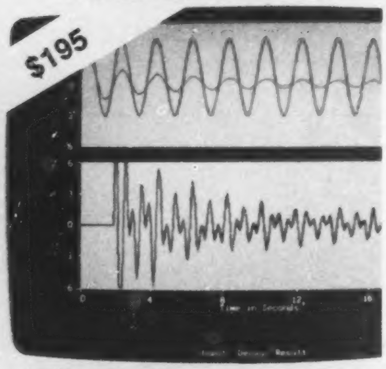

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OPINION POLL RESULTS

Much research not reported

RESULTS of many research projects are not shared with he scientific community, a recent survey of *Research Development* readers reveals.

More than half of the respondents do not report more than some of their work. And, for half of those, he reason is that the information is considered proprietary.

Complete results of the survey follow:

1. *What portion of your research work do you tell the scientific community about?*
   a. all 7% b. most 33% c. some 48%
   d. none 12%
2. *Of the work you don't tell others about, why don't you?*
   a. national security 8%
   b. proprietary reasons 54
   c. not deemed to be significant enough 28
   d. no incentive to do so 10
3. *In what form do you tell others of your research?*
   a. publish in society journals 19%
   b. publish in periodicals such as *R&D* 3
   c. presentations at symposiums 23
   d. all of the above 37% e. other 18%
4. *How does your organization compensate you for your publishing efforts?*
   a. extra money 8%
   b. time off 2
   c. allowed to write on company time 47
   d. no compensation 43
5. *How does your organization feel about publishing research results?*
   a. expect you to publish as often as possible 37%
   b. whether to publish is left to your discretion 38
   c. you are discouraged from publishing 18
   d. you are not allowed to publish 7
6. *Do you enjoy the work involved in publishing the results of your work?*
   a. yes 64% b. no 14% c. indifferent 22%
7. *When you want to find out what others are doing in your field of research, where do you look?*
   a. society journals 56%
   b. other single-topic journals 15
   c. trade magazines such as *R&D* 15
   d. symposiums 8
   e. personal communications 6
8. *How many research reports do you read each month?*
   a. 0 to 5 29% b. 6 to 10 33%
   c. 11 to 20 23% d. more than 20 5%
9. *Do you keep files of articles and research papers that describe work others have done in your field?*
   a. yes 96% b. no 4%
10. *On a scale of one to five, with five being most important, how important is the practice of publishing research results?*
   a. 5 53% b. 4 29% c. 3 12%
   d. 2 3 e. 1 2

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Research Development

DECEMBER 1987

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The magazine with the
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ABOUT THE COVER

Statistical techniques let scientists and engineers design experiments to identify conditions for maximum yields of products. Cover photo made for *R&D* by Stephen F. Grohe.

An article on experiment design begins on p 54.

NEWS

39 **Science policy:** U.S. wavers on issue of access to computer data bases; NSF funds experimental computer research

40 **Fusion:** Many problems remain in fusion energy development; experiment points to existence of fifth force

41 **Lasers:** High efficiency keys interest in visible chemical lasers

41 **Computers:** Advances in electronics spur interest in neurocomputers; Sweden's investment in R&D pays off

45 **Awards:** Nobel committee is quick to recognize work on superconductivity; innovative lab design sought; *R&D 100* emphasizes role of applied research

48 **Physics:** Soviets plan to build a massive linear accelerator

49 **Processing:** Chemical reaction methods used to make ceramic materials

ARTICLES

54 **Assure product quality by using applied statistics:** B.A. Jones, BBN Software Products Corp.; experiment design for improved yield and quality.

62 **Helium-3 researcher makes 1-mK measurements attainable:** T.A. Heppenheimer; low-temperature atomic studies.

65 ***R&D* Reader Survey: Most-significant advances:** readers say harnessing electricity is most important.

68 **Twenty-five years of *I-R 100* awards, a story of changing technology:** Robert R. Jones, Editor, *R&D.*

71 **Dilute silane mixtures make PECVD systems safer:** A. Kiermasz, A.A. Chambers, and A. McQuarrie, Electrotech.

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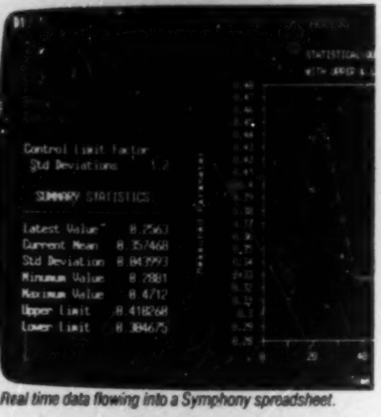

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Control Limit Factor
 Std Deviations      1.2

  SUMMARY STATISTICS

Latest Value      0.2563
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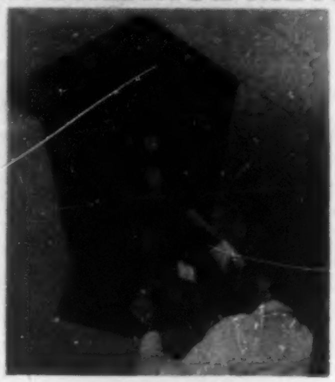

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OPINION POLL RESULTS

Computers don't dominate

A RECENT survey of *Research & Development* readers suggests that computerized data acquisition is not an integral part of the research process.

More than 60% of the respondents acquire data manually and either record it in a notebook or enter it into a computer for analysis. Only 26% of those responding use computers as a tool for sharing data with their colleagues.

Results of the survey follow:

1. *How do you currently acquire data in your laboratory?*

Data are collected manually, using	
a. strip chart and notebook method	26%
Data are collected manually, then entered into a computer for analysis, using	
b. personal computer	30%
c. intermediate-sized computer (larger than an "AT")	6
d. mainframe computer	4
Data are fed directly from instruments to computer without human intervention, using	
e. personal computer	19%
f. intermediate-sized computer	13
g. mainframe computer	1

2. *Within the next year, do you have plans to upgrade your data acquisition system by either*

a. purchasing your first computer	11%
b. expanding the capabilities of your existing system	61
c. neither	28

3. *How is research information shared with other departments/laboratories in your organization?*

a. photocopies of data sheets	69%
b. trading flexible disks	11
c. computer modems	3
d. some form of local area network	12

4. *What percentage of your tests involve overnight data acquisition?*

a. have never used it for overnight acquisition	38%		
b. 1 to 10%	31%	d. 26 to 50%	8
c. 11 to 25%	12	e. 51% or more	9

5. *How long did it take to gain enough proficiency with your data acquisition system to make it useful to you?*

a. 1 month	34%
b. 6 months	38
c. 1 year	11
d. never have become proficient	9

6. *How does your data acquisition system meet your expectations?*

a. does more than I expected	12%
b. does about what I expected	63
c. does less than I expected	14

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Research & Development

JANUARY 1988

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ABOUT THE COVER

This year will bring new emphasis on superconductors. This one uses a vanadium barrier to contain tin within conducting wires. When heated, the tin and niobium react to form Nb_3Sn.

Micrograph by P.E. Danielson, Teledyne Wah Chang, Albany, OR, furnished by Carl Zeiss Inc.

NEWS

33 **Space:** NASA looks optimistically to the new year; ESA shifts emphasis to manned missions; British decision cripples its space efforts

34 **Superconductivity:** Researchers report superconductivity at 500 K; British officials chart their research efforts in superconductivity

35 **R&D funding:** Delays in approving Alvey successor signal change in UK

35 **Environment:** Recent quake holds new dangers for California; consortium aids small-business interests

37 **Technology export:** Revelations of tech diversions help and hinder U.S. security

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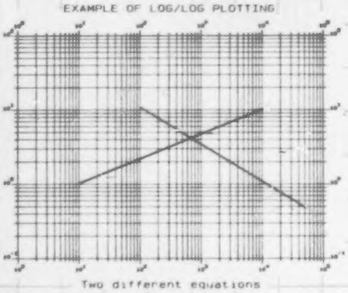
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R&D funding in U.S. will hit $132 billion in 1988

Barring further economic calamities, total funds available for research and development will increase adequately to allow some small real growth this year.

C.J. Mosbacher
Consultant, *R&D* magazine

BLACK MONDAY, Gramm-Rudman-Hollings or a budget compromise between the Administration and Congress, a falling dollar, and a continuing trade deficit: Will these factors cause a research and development recession in the United States? From what we have been told by leaders in industry and in government, academia, and other nonprofit organizations, the answer is a definite NO.

On that same basis, coupled with consideration of available data on research and development funding and expenditures, we project funding of $132 billion for R&D in the calendar year 1988.

Portions of the data are from studies and projections of the general economy, business, and industrial sectors provided by the Economics Dept. of Cahners Publishing Co. Comments and tabulations of economic indicators that accompany this article were provided by that department.

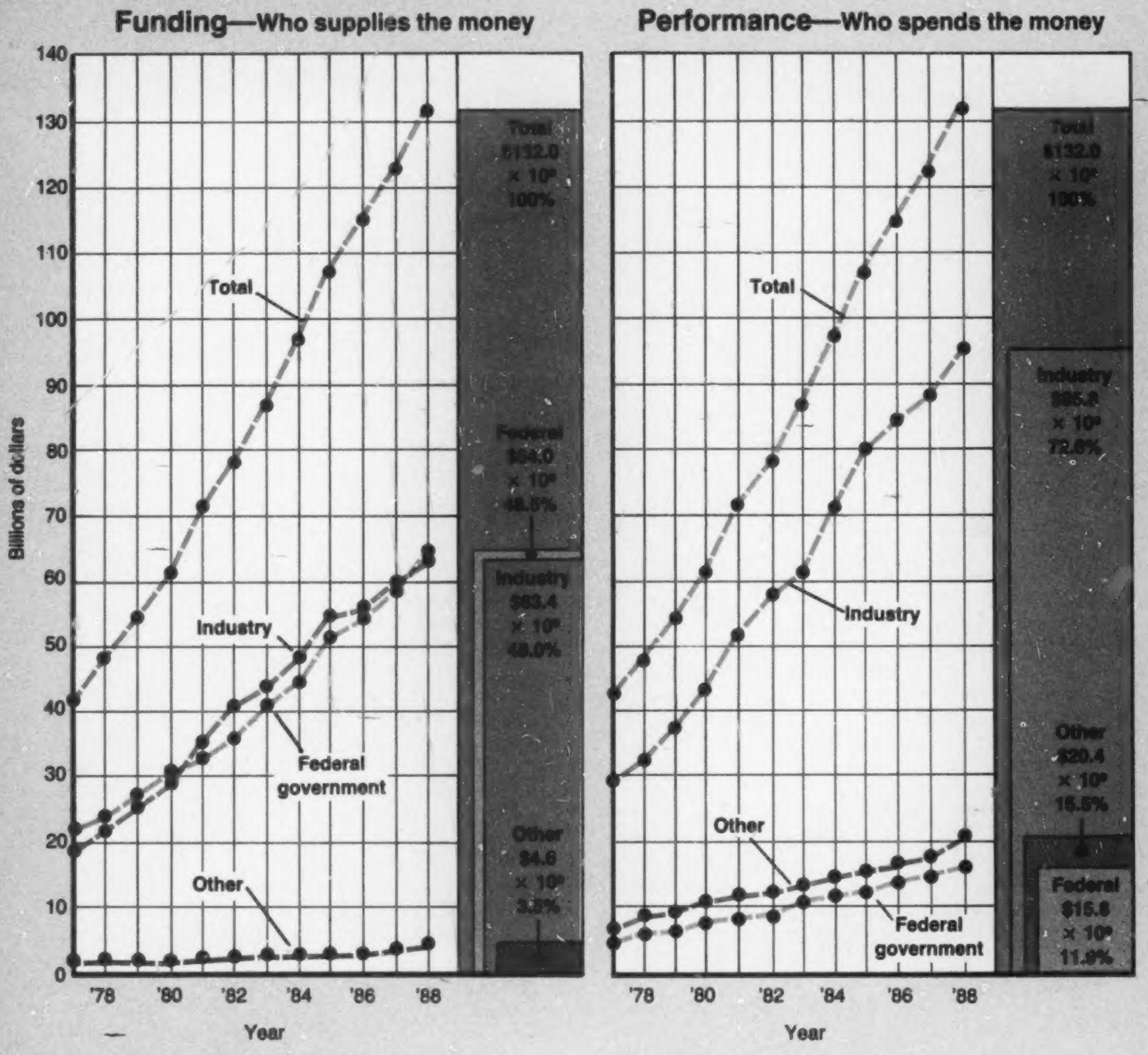
A year ago, this Forecast projected 1987 funds for research and development of $125 billion. As explained later in this article, information now available has resulted in a revised 1987 funding figure of $123.6 billion. An increase of 6.8% overall leads to the 1988 funding levels forecast here.

The 1988 total includes funding of $63.4 billion from industry, $64.0 billion from the Federal government, and $4.6 billion from other sources including universities, colleges, and other nonprofit organizations. As percentages of total 1988 funding, industry is projected to provide 48.0%, the Federal government 48.5%, and other sources 3.5%. Essentially, this is the same sectoral pattern for funding as in 1987. The only difference is a shift of 0.1% from industry to the "other" sector.

Considering transfers of funds among sectors, we can project where expenditures will be made for the performance of research and development. Our forecast is that industry will use $95.8 billion in 1988, while Federal government laboratories will use $15.8 billion and other sectors $20.4 billion.

Thus, industry will spend 72.6% of the total dollars available in 1988, the Federal government 11.9%, and other sectors 15.5%. The comparable performance percentages for 1987, based on our revised total of $123.6 billion, are 72.4% for industry, 12.4% for Federal government, and 15.2% for other sectors. Whether these slight changes constitute the beginning of a trend toward more performance of R&D by the academic and nonprofit sectors cannot be established now.

However, in 1987, the number of industry cooperative R&D organizations that was established increased noticeably. In particular, the Dept. of Defense was proposing a $100 million addition to the fiscal 1988 budget for Sematech (a cooperative venture that will use matching funding from industry to develop new



techniques for semiconductor production) and a National Science Foundation program for establishing targeted R&D centers at universities with joint government-industry funding.

In addition, General Electric's gift of the RCA David Sarnoff laboratories to Stanford Research Institute, after GE acquired RCA, in effect transferred $88 million of performance funding from the industrial to the nonprofit sector.

Revisions affect 1986 and 1987 data

As has been our practice in past years, the first step in preparing this forecast is to review and revise earlier forecasts. For example, shortly after the 1987 Forecast was published (*R&D* January 1987, p 68), the National Science Foundation published its "Science and Technology Data Book" (NSF 86-311). It estimated 1986 total research and development at $117.5 billion. Our revised 1986 forecast was $118 billion.

For 1987, the NSF estimate (in NSF 86-311) was $125.2 billion. Our forecast was $125.0 billion. For comparison, the NSF estimates and our forecasts by sector can be expressed in billions of dollars as NSF/*R&D* magazine for funding: industry, 60.5/61.0; Federal government, 60.5/59.8; other, 4.2/4.2. For performance, the comparison is: industry, 91.0/91.0; Federal government, 15.4/15.2; other, 18.8/18.8.

As 1987 progressed, more and more published data indicated that while our forecasts for the Federal government and the academic–nonprofit sectors would

The 1988 U.S. economy in a nutshell

R&D IS BEST VIEWED in the context of the changes that are occurring in the general economy and in industry. Cahners Economics has provided these more-general forecasts and data especially for this Forecast article.

General economic outlook

The outlook for U.S. economic growth took an unprecedented dive in the last quarter of 1987 on the heels of the stock market free-fall and subsequent jitters in the financial markets around the world. Cahners Economics, however, continues to remain relatively optimistic and forecasts real gross national product to grow by 3.1% in 1988. Clearly, this is just average growth, but no recession is looming in the near term.

Our outlook is predicated on a number of factors. First, the current economic expansion is no longer being led by the consumer sector but, instead, by an upturn in the industrial markets. Furthermore, the outlook for consumer spending may not be as bleak as some reports suggest. Even with the post-Black Monday blues and a short-term pullback on purchases of durable goods, consumers are expected to maintain steady spending for nondurables and services throughout the year.

Second, on the investment side, businesses will be throwing a bit more money into their capital spending budgets, especially for equipment. Total manufacturing and new plant and equipment spending will increase by 9.6% by the end of this year as a result of improved profits and trade position. Finally, we expect some restocking of low inventory levels as businesses regain confidence that growth is real. This will continue for at least the next 12 months.

After-tax corporate profits

After two years of declining corporate profits, U.S. industry will see profits increase almost 13% this year, reflecting healthy business conditions. As economic expansions mature, profits have traditionally increased. Also, businesses begin to approach capacity constraints, lead times begin to lengthen, and businesses find that in such an environment they can raise margins.

This has been particularly true during this business expansion because of the declining dollar. U.S. exports are more attractively priced in foreign markets, and U.S. businesses can use this strategic advantage to regain market share or increase margins.

Business investment

The improved trade situation, increased profits, and relatively reasonable interest rates will have a positive effect on business investment. Although investment in 1987 increased less than 1.0% compared to 1986, investment in 1988 will increase by about 6.3%. This certainly is not the rate achieved in the early 1980s, but is respectable nonetheless. Nondefense capital goods spending is expected to outpace defense capital goods outlays, and growth in equipment spending will be greater than investment in structures.

New manufacturing plant and equipment spending will make a major contribution to investment growth in 1988. However, not all industries will participate equally in this investment miniboom. The chemical and nonelectrical machinery industries are expected to increase their investment spending by much more than 10%. By comparison, the auto industry, which invested billions of dollars in 1984 and 1985 in an attempt to remain competitive, will not have such large growth in capital spending budgets for some time to come.

Total industrial production

Industrial production has been expanding since the beginning of 1987. Total production will grow 6.3% this year on top of 3.7% in 1987.

Posting the biggest gains will be the electronics markets as both equipment and components recover from their low levels of activity over the past few years. Other equipment and machinery markets also will do quite well as manufacturers increase their capital spending and the decline in the value of the dollar opens up foreign markets.

Process industries

The process industries have been the stronger half of the manufacturing sector since the current industrial recovery began, but their superior position will be eroded as the recovery in the OEM markets gains momentum. The process industries will continue their pattern of steady, if unspectacular, growth. After an increase of 4.9% in 1987, process output is expected to rise another 4.9% in 1988 before dropping slightly in 1989.

OEM industries

The industrial production indices that measure the output of the OEM industries have been steadily advancing since the first quarter of 1987. The aggregate index for the OEM industries computed by Cahners Economics is up 3.3% since December 1986. Increases in shipping activity by manufacturers in the OEM sector have closely followed the production increases—total shipments through the first three quarters of 1987 were up 3.8% over the same period last year.

Despite the fluctuations in the financial markets, the outlook for the OEM industries through 1988 is for continued growth. Unemployment is low, and foreign demand for U.S. goods is increasing because of the weaker dollar. The unpredictable psychological effects of the stock market drop and the budget and trade deficits may result in a muted expansion, but 1988 will still be a good year for most manufacturers in the OEM sector, particularly electronics. Total OEM output will increase 7.3% by year-end 1988.

Comparative prices

At the end of the third quarter of 1987, nearly 75% of the buyers surveyed by *Purchasing* magazine reported price increases for industrial commodities. That is the highest level since the current expansion began five years ago.

Industrial prices will continue to rise well into 1988, in many cases by 20% or more. The increases will be more widespread this year, as rising import prices and growing export demand puts added pressure on suppliers of basic industrial commodities. In addition, wage inflation, which has been very slow for the past few years, will begin to fuel prices this year.

need only slight revision, industrial funding and performance would have to be substantially reduced.

For example, in its "R&D Scoreboard" (June 22, 1987), *Business Week* magazine reported that the 859 companies topping the list of R&D spenders in industry had expenses of $50.9 billion in 1986. The *Business Week* annual scoreboards are traditionally lower than either our forecasts or NSF data, but not significantly lower.

Such data led us to seek more information about 1986 and 1987 funding and expenditures as we discussed plans for 1988 with leaders of industry, trade associations, academia, nonprofit groups, and government. We found that we had misjudged the timing of a significant downturn in the rate at which industry was increasing its R&D funding.

Annual increases of more than 12% prior to 1984 did not continue but started a drop to an average rate of about 6% from 1984 through 1987. A principal cause of the lower growth was that sales and profits were lower than expected in many parts of industry. Short-term profit goals adversely affected industry funding of basic and applied research, and tax changes impacted corporate after-tax profits in 1987.

Mergers and attempted mergers also limited funding for research and development as corporations restructured financially and took on additional debt burdens. An extreme example was the closing of Borg-Warner's research center as part of a defense against an unwanted takeover.

Backtracking, we revised our industry funding levels to $56.5 billion for 1986 and to $59.4 billion for 1987. That is a 2.6% reduction for both years.

For Federal funding, our studies led us to reduce the 1986 figure from $56.0 billion to $55.5 billion. For 1987, we increased the figure from $59.8 billion to $60.0 billion, primarily because appropriation delays shifted some funds from the first quarter of fiscal 1987, which started on October 1, 1986, into calendar 1987.

For the other—academic and nonprofit—sector, our studies led us to retain our previously revised 1986 funding figure of $3.9 billion, as well as the $4.2 billion figure originally forecast for 1987.

Combining these data resulted in a re-revised 1986 total funding figure of $115.9 billion, 1.8% less than the revision included in last year's forecast of $118.0 billion for 1986. For 1987, the result is total funding of $123.6 billion. That is a decrease of 1.1% from the $125 billion forecast of a year ago.

Performance data for 1987 resulting from these revisions were given earlier in this article as percentages for comparison with the 1988 forecast. The actual dollar revisions were a decrease from $91.0 billion to $89.5 billion for industry; an increase from $15.2 billion to $15.3 billion for Federal laboratories; and no change in the academic–nonprofit sector at $18.8 billion.

The balance of this article is devoted to discussing the factors that influence the funding provided by each sector and the performance of R&D by each sector as funds are transferred and spent.

Industry: funding up 6.8%, performance up 7.0%

Corporate profitability improved in the second half of 1987. Cahners Economics forecasts a healthy increase of almost 13% in 1988, along with real growth in GNP of 3.1%. With inflation, total GNP will increase 6 to 7%. We expect industrial funding of R&D to increase 6.8%.

Not all parts of industry will experience equal growth, either overall or in R&D. The largest growth is expected in nonelectrical machinery, a category that includes computers (because the first "computers" were punch-card sorters and it is hard to change established statistical categories because of the expense of revising past data). Advances in computer technology are coming so rapidly that firms have no choice but to fund ongoing R&D if they are to remain competitive.

Other areas in which good growth can be expected are pharmaceuticals and biotechnology, electronics, and instruments and test equipment, the latter being primarily affected by the electronics area. Despite the improving economic picture for the petroleum and primary metals industries, R&D funding is not expected to increase in those areas.

The worst news for R&D is in the automotive sector. Production cuts and costly incentive programs, designed to boost sagging sales, will curtail funding.

Federal funds support much of industry research and development. Taking this into consideration, performance of R&D by industry is expected to increase 7% in 1988.

Federal: funding up 6.7%, performance down 3.3%

The original budget submitted by President Reagan included $62.4 billion for R&D in fiscal 1988. With cutbacks for deficit reduction, the R&D forecast of $64.0 billion for calendar 1988 seems impossible. The explanation lies primarily in how the U.S. government operates.

Congress modifies the budget and passes its own budget resolution. Authorization bills specify what activities are to be supported and, finally, appropriation bills authorize expenditures. Then the Executive branch obligates the funds to specific activities and contracts, which may include actual spending in later years.

In 1988, once again, a significant carryover from earlier fiscal years continues to support R&D. In effect, this tends to average out changes in Federal sector funding.

But, when deficit reduction rears its head, those in R&D pay attention. Every source of R&D funds in the Federal government is in the "controllable" portion of the budget—the part that is easiest to cut. If Gramm-Rudman-Hollings had been fully implemented, Dept. of Defense R&D activities would have suffered. One scientist calculated that only funds for salaries would be available in DOD laboratories, leaving no money to support other R&D costs.

But in the civilian sector, funds for research and development would have been subjected to a cut of 8.5% if cuts were distributed evenly over the controllable portion of the budget. In most cases this would have led to a net increase in R&D funding. President Reagan's budget had called for an 8% increase. Both the Administration and Congress had added items to the civilian portion of the budget. Our calculations indicate that Federal funding, outside DOD, would have still been about 2.5% larger than in fiscal 1987.

The inability of Congress to pass budget and appropriation bills until late December also had the effect of pushing funds into calendar 1988.

Performance of R&D in government laboratories is expected to decrease in 1988, partly because of cutbacks in the energy and pollution fields from the high levels of earlier years, and partly because of efforts to hold down "in-house" costs in administering external programs.

Others: funding up 10.0%, performance up 8.5%

While this sector has the largest percentage of increase, the dollar amounts are comparatively small. Increasing overhead costs lead to a need for increased self funding, particularly when new cooperative ventures are being negotiated and after they are formed.

Inflation or real growth?

Cahners Economics forecasts a 3.1% increase in gross national product in 1988, expressed in constant dollars based on the worth of a dollar in 1982. To express GNP increases in current dollars, an inflation factor has to be added. Any of several factors can be used.

Cahners Economics is forecasting 1988 inflation as 3.8% in the consumer price index, 4.1% for imported consumer goods, but only 3.0% for producer and industrial prices. Federal government agencies use an implicit price deflator that is set and mandated by the Office of Management & Budget.

No measure of inflation has been established specifically for research and development. Because salaries constitute a substantial portion of R&D costs, we feel that such a specific factor would lie between the consumer and the producer price indices. In that case, the R&D field can expect to see real growth in 1988 that is somewhat higher than the forecasted growth in gross national product.

That is better than might have been expected amid the squalls of this past fall. On the basis of this Forecast, real growth is expected to be just slightly higher than that of the gross national product. **R&D**

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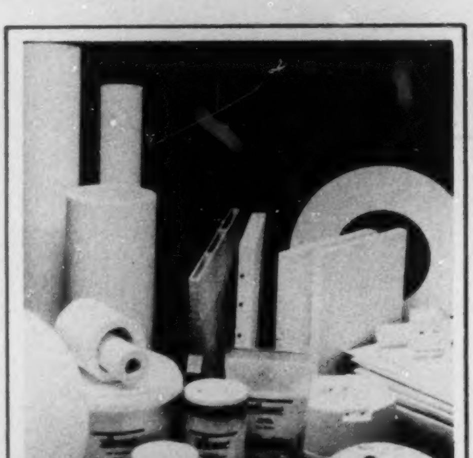
C.J. Mosbacher has continued as a consultant to *Research & Development* magazine since he retired as Executive Editor on January 1, 1986.



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CIRCLE **131** ON INQUIRY CARD

FARMER COOPERATIVE NUMBERS AND MEMBERSHIPS, 1986

Component	Cooperatives	Memberships
	Number	
Products marketed:		
Cotton	396	94,749
Dairy	345	152,881
Fruits & vegetables	344	61,880
Grain and soybeans	1,514	909,643
Livestock, wool & poultry	469	450,120
Rice	49	20,600
Sugar products	40	8,020
Other (beans, peas, nuts, tobacco & miscellaneous)	103	315,031
Total farm products	3,260	2,012,924
Total farm supplies	1,971	2,225,550
Total services	138	163,283
TOTAL	5,369	4,401,757

Note: Information is preliminary. Many cooperatives are multiproduct and multifunctional in operations and are classified according to predominant commodity or function indicated by business volume.

Source: "Farmer Cooperatives," October, 1987, page 6, published by the Agricultural Cooperative Service, U.S. Department of Agriculture.

million, up from $347.5 in 1985. More than half of the sales are to foreign countries.

Growth has come through finding new uses and new markets. *Blue Diamond* almonds are used in more than 2,000 different ways and sold in 88 foreign countries.

The world's largest

The Tree Top cooperative in Selah, WA, world's largest apple processing company, had retail sales of $187 million last year. Total sales by the company accounted for one-sixth of the state's $3 billion ag industry.

The crops of the more than 3,800 grower-members are processed in one of the co-ops four processing plants into a wide range of juice products, concentrates, frozen, and dried products.

John McAlister, director, public affairs, credits the success of the co-op to responsive and aggressive marketing.

But being a co-op, says McAlister and many of his co-op counterparts, "is a mixed blessing." When times are good, everything is fine. But "there is always a shortage of capital for future expansion. If we want to develop new products or build a new plant we are very limited to the amount of capital resources we can extract from the co-op," he says.

Building consumption

Riceland Foods, Inc., Stuttgart, AR, a co-op of 11,500 farmer members in Arkansas and nearby states, is the largest miller of rice in the U.S., the nation's fifth largest grain storage company and a Fortune 500 company. "Each year," says Bill Reed, vice president, corporate development, "we mill and market approximately one-half of the Arkansas rice crop, which figures to be about 20 percent of the U.S. rice crop."

They have been leaders in what they do best: marketing rice. Per capita consumption of rice is now 17.4 pounds, up from 9.1 in 1975. By finding international markets and working with federal programs, the co-op has been able to work off their surplus. U.S. rice is now sold into roughly 75 different countries by Riceland.

Riceland also has an edible oil operation producing a wide range of soybean oil products and the co-op is one of only two manufacturers of oil-free lecithin in the U.S. Riceland products are marketed under the *Riceland* and *Chefway* names.

Looking to the future

Despite the difficulties of recent years, there is optimism heading into the 1990s. Says Ralph Hofstadt, president of Land O'Lakes, "I'm very optimistic, but only if this group of organizations can clearly see the kind of business environment they will be operating in. It will be volatile, but very exciting. We have to develop new programs and change present structures."

What the co-ops have to look forward to is continued merger, acquisition and joint venture activity. They must continue to market aggressively, both internationally and domestically. The battle for share of market will continue to be waged around the globe.

At Sun-Diamond's cannery operation, shelled walnuts are routed to cans where they are automatically filled.

Special Emphasis

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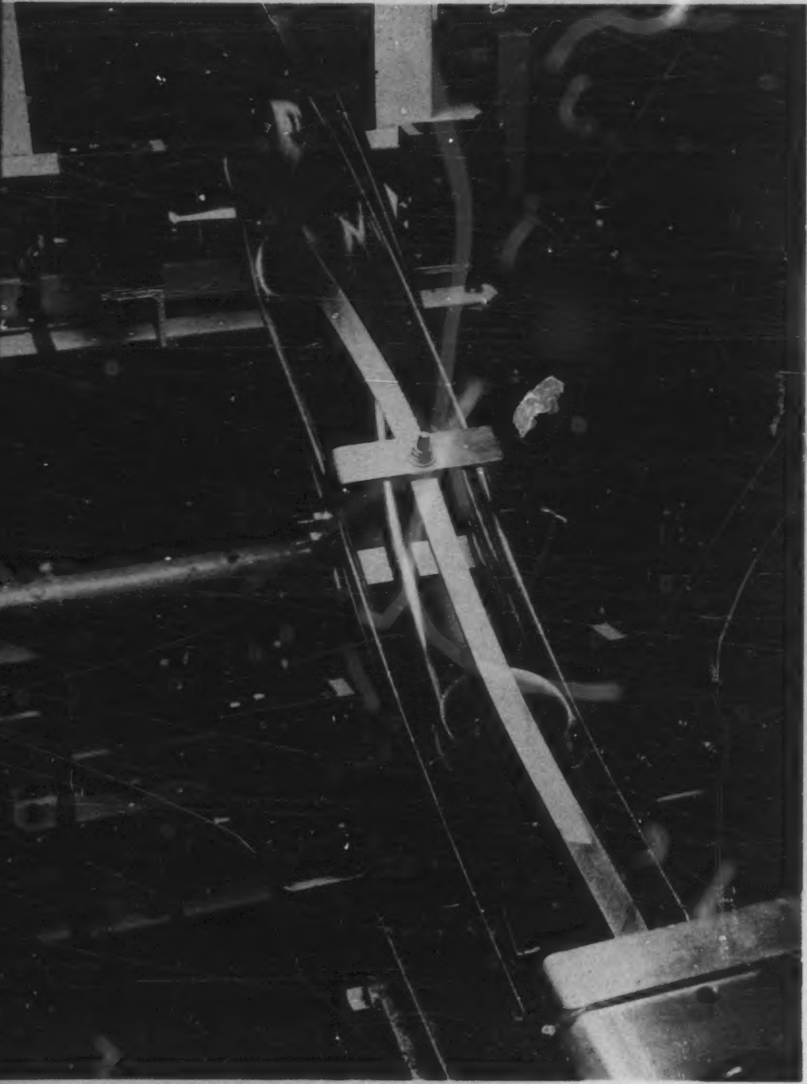
CANNING INDUSTRY: METAL VS. PLASTIC

Closing and inspection systems offer speed, efficiency, and product integrity to the traditional can line. But the metal can line may be affected by a new force in packaging design: plastic cans.



Photoelectric sensors from Omron Electronics monitor operations on a high-speed canning line. The sensors are able to detect jams on the line.

Canned foods and the canning industry have been around for so long that they are often taken for granted. In 1810, Nicholas Appert, a Frenchman, published the first book on canning methods and introduced a new form of food preservation. As a result, canned foods were most likely the first convenience foods.

While the advent of plastics and plastic cans is beginning to mean additional competition, the metal can still has continued to maintain a strong position in the food industry, most notably in beverages.

Recent trends in fact indicate that metal can manufacturers can expect significant growth over the next decade. The amount of can sales to major end-group users, (excluding pet foods), according to the Can Manufacturers Institute, Washington, DC, shows that 23.4 billion units of cans were sold in 1986. In the beer and soft drink category, 72.9 billion cans were shipped to manufacturers in 1986.

The most recent estimates for 1987, according to the U.S. Industrial Outlook of the U.S. Department of Commerce, show that 27.2 billion units of metal cans were shipped to major end-group users. And, in the beer and soft drink area, 78 billion units were shipped to manufacturers during the same time period.

Canning equipment

Because the canning industry is always looking to improve processing methods and to enhance product quality, safety and efficiency, canning and seaming equipment and the inspection systems to accompany them have reached an extremely high level of speed and accuracy.

For example, Continental Container Systems, a division of Continental Can Compa-

MARGIE J. RUSSELL
Senior Associate Editor

ny, Inc., West Chicago, IL, has several lines of closing machines, the most versatile being the *2000 Series*, three basic units which can accommodate a wide range of packaging. The *2003 RCM1* three-spindle machine will close 401 through 610 diameter cans at speeds up to 300 cpm. The *2004 RCM1* four-spindle machine closes 202 through 408 diameter cans at 400 cpm. And the six-spindle *2006 RCM1*, will do 202 through 404 diameter cans at 600 cpm.

The 2000 series is designed for height changeovers that can be done in several minutes, because of a new design that provides for the support and driving of all height-change-related components directly from the machine's upper housing. This eliminates the need for sliding shaft and key fits.

Another major supplier of seaming equipment, Angelus Sanitary Can Machine Company, Los Angeles, CA, has a straight-line feed seamer, *model 61H*, that provides high-speed operation with semi-automatic lubrication to minimize downtime and maintenance costs. Cans are seamed at high speed in a six-spindle "can spin" turret. Each spindle has durable, large-diameter first and second operation seaming rolls mounted on tapered roll bearings. Seaming rolls can be individually adjusted for height and seam thickness.

A closing machine which meets the industry's needs for speed, reduced spillage and low maintenance costs has been introduced by FMC, Madera, CA, as the *FMC 952*. This model is a sixteen-spindle closer using can rotating seaming principles which means that it runs faster but at the same time, provides gentler handling of lightweight cans because of lower seaming. The 952 reduces spillage through effective can spacing of the closer infeed chain and seaming head. This allows ideal synchronization to all of the fillers and minimizes can acceleration. The machine, used mainly for beverage, closes up to 2000 cpm.

Hema International, Sandy, UT, has a vacuum seamer, *model SHV60*, which is designed for round and odd-shape containers. This is an automatic seamer which can be adapted to a particular application. The seaming head allows first and second seaming operations, and is mounted on a heavy duty, articulated arm, allowing the head to swing out of the main frame. Adjustments and changeovers are easy. The SHV60 runs at speeds of 15 to 120 cpm depending on the size of the container. In addition, Hema is developing a new model which will allow speeds up to 200 cpm, and will also greatly facilitate adjustments and changeovers.

Inspection systems

Even though it is usually fast and efficient, a canning operation is only as good as its monitoring system. The canning operation's accuracy depends on two main factors: that seaming equipment is operating correctly and inspection/detection systems for poor vacuum, incomplete fills and defective cans are operational.

The integrity of double seams is of vital importance in the canning process. With the speed and complexity of current equipment, visual inspection of random samples from the line is no longer acceptable to maintain a high quality product.

For this reason, new technologies have been developed for inspection on the line, one of which is Continental Can's *In-Line Double Seam Tightness Monitor*. The In-Line Monitor allows 100 percent monitoring of double seam tightness for every can before it leaves the closing machine with no effect on speed. An acceptable pressure range curve between the rolls and the chuck is selected, and the monitor matches the image of the actual pressure curve around the seam against the parameters in the software. The system alerts the operator of out-of-limits conditions through a status printer and monitor warning system. The removal

Major markets for metal food and beverage cans (Millions of dollars)

Year	Manufacturers' Sales of Metal cans	Annual Percent Change	Soft drinks, beer	Fruits, Vegetables, Juices	All other foods
1984	$11,621.4	10.1	7,640.6	1,743.7	2,128.4
1985E	12,667.1	9.0	8,463.5	1,975.6	2,228.0
1986E	13,304.6	5.0	8,810.0	2,090.2	2,404.4
1995P	25,120.0	7.0*	17,079.4	3,639.4	4,401.2

*Compounded Annual Average E – Estimate by BTA P – Projection by BTA
Source: U.S Department of Commerce; Business Trade Analysts

of questionable containers is accomplished by one of two optional integrated reject mechanisms.

The Double Seam Monitor is available as an option on new Continental Can rotary closing machines. It is also available as a retrofit for the existing 2000 Series.

Along the same lines, Dun-Rite Products, Barrington, IL, offers its *Double Seam Monitor System (DSM)*, which performs single or double can end sampling anywhere within the can line system. As a can is transferred onto the DSM system, it is stabilized, metered and positioned through the sensing zone. The can is rotated three times in front of the sensing bar assembly and the double seam is sampled for defects. If the double seam qualifies, the can remains on the line. If it does not qualify, the can is ejected from the line for inspection.

The DSM system can be incorporated into existing can lines for sampling of one or both double seams. The monitor system can sample up to 350 cpm. A built-in controller maintains proper can traffic on the line and Dun-Rite advises that cans should not idle on the DSM system.

Another form of on-line monitoring is vacuum inspection, which uses sensors to detect containers with poor vacuums. When a metal surface is stressed by vacuum, it is drawn into a concave shape. Greater vacuums will create greater deg[illegible] of concavity. These systems reject con[illegible] when the vacuum is insufficient to pull th[illegible] can end inward beyond a threshold valu[illegible] locked in a sensing panel.

Key Technology, Walla Walla, WA, offers the *1200 Series of Dud Detectors*, which tests both ends of a can concurrently. Sensors located under the belt and in the top reference assembly measure can lid deflection and compare the readings to adjustable set points. Low vacuum cans and leakers are removed from the line at up to 1200 cpm.

Peco-Controls, Milpitas, CA, offers its *VAC-TRAC* dud-ejector system which checks each container for end-deflection by a three-point proximity sensing method. Each container passes under the sensor head, where outer sensors measure and average reference depth at the container's outermost edge. A middle sensor measures depth at the center on the container's end. Container end deflection is determined by subtracting the center-end measurement from the average signals on the outermost edge. The system has the capability to scan at 750 cpm.

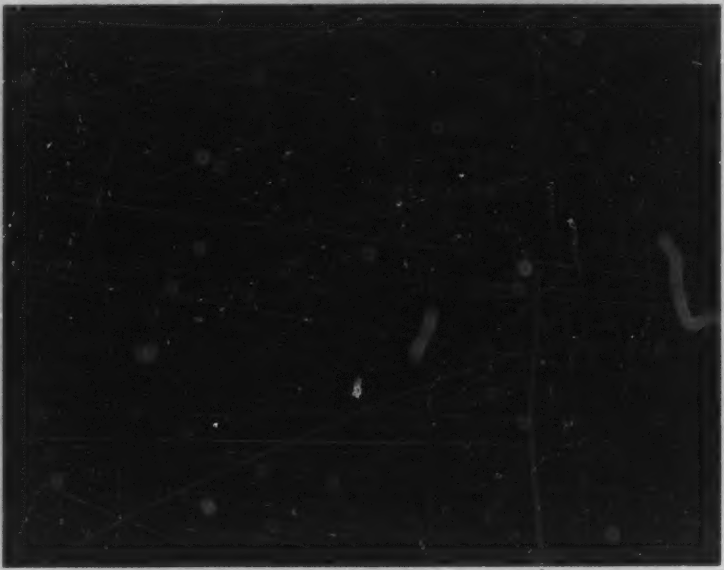
An inspection system which is used on dedicated can lines from 202 size or greater is available from TapTone Container Inspection Systems, a division of Benthos, Inc., North Falmouth, MA. The *Standard Vacuum Profiler* uses a sensor to define a can end and can scan up to 1200 cpm. As a container passes under the sensor, a measurement is made defining the shape, or profile, of the container end and sensor output will vary according to the shape of the surface.

In the case of a can end, the Profiler measures and responds to the degree of curvature of the end, which is electronically measured and compared with a preset "good" and "bad" profile. The system has a circuit concept which electronically stores these profiles. Assuming the production process is controlled, the curvature should remain consistent. If vacuum is lost, the curvature or the profile changes. A proportional readout indicates the degree of vacuum. The Profiler senses this profile change, and rejects the container with the defective profile.

Specialized systems

Inspection, however, is not just a matter of safety, and that is where a photoelectric sensor system, like that available from Omron Electronics, Schaumburg, IL, is ideal to check for proper can orientation. Omron's sensing system consists of a pulse-modulated infrared LED and special reflector and aspheric lenses. When used with a programmable controller, these sensors, the Omron *E3S-R* and *S3D8*, and the controller are able to detect upstream and downstream jams on the line. When the sensor detects the presence of cans, the PC uses internal timers to check if cans are not moving past the sensor at regular intervals (upstream jam) or are sitting still on the line (downstream jam).

This vacuum seamer, model SHV 60, from Hema International, operates according to the double seam principle and can accommodate a wide range of containers.



The Angelus seamer, model 61H, provides high speed operation with semi-automatic lubrication to minimize downtime and maintenance costs.

The system will then reject or re-route the appropriate containers.

A new trend?

Are plastic cans the wave of the future in the canning industry? They may be, because, plastics have entered the canning marketplace bringing with them great capabilities.

Products packed in plastic containers are lighter in weight than their metal counterparts and are easily stored. They are microwaveable, which right now is a large plus. Presently, plastic containers are more expensive than metal cans but there is evidence that the cost gap is closing. It is believed, however, that small processors cannot afford a changeover to plastics until the price of the containers becomes at least comparable to metal.

The "Omni", for example, is a rigid plastic can developed by American National Can Company, Greenwich, CT. Composed of polyolefin, it is white, with one metal end where the seaming operation occurs. The container is retortable and has a high oxygen barrier, giving the packaged product a long shelf life. Probably the best consumer advantage of the container is that it is microwaveable. The container cannot be recycled but can be fully incinerated, giving off no harmful by-products.

According to American National Can, the Omni container can be used on any existing seaming equipment with some slight modifications. Currently, Hormel Co. is the only processor that is using the Omni can for its meat-based products. In addition, American National Can will be marketing several more Omni can applications in the first quarter of 1988. The containers will be both cylindrical and bowl-shaped.

The newest entry into the plastic can market, the Petainer, was developed by the Petainer Development Company, Atlanta, GA. It is currently being used for beverages in several test markets.

The Petainer can has a standard aluminum lid, is of low barrier layer construction, and has a PVC label. The container has a 15-16 week shelf life but cannot be used in a retort system. The Coca Cola Company had, until recently, test marketed the Petainer exclusively. Original New York Seltzer has since picked up on the use of the Petainer and has launched five of its ten flavored drinks in several test markets, two of which are Detroit and Boston. The container can be run on standard seaming equipment.

However, what if both ends of the can are plastic? We talked to Akerlund and Rausing, of Lund, Sweden, which has introduced its form of the plastic container into the Swedish market under the trade name *Letpak*.

Letpak is a three-piece container in which the can's case, lid and base are composed of polypropylene with a thin barrier lamination of aluminum. One end is sealed to the body by the manufacturer, the other is sealed at the point of fill. Inductive high-frequency welding gives the container a perfect seal.

According to Akerlund and Rausing, the container can be run on standard canning equipment with the addition of a special Letpak sealer. If magnetic conveyors are used on the line, they too must be changed. The line can run up to 200 cpm.

Presently three fruit products packed in the container have been test marketed in Sweden. Letpak has been developed for the worldwide market and will be widely available by 1990.

Here to stay

Most packaging authorities and forecasters will agree that the plastic can is here to stay. The advent of the plastics industry has forever changed the scope of packaging. It is interesting to note, though, the metal institutional can, number ten, has been untouched by the plastics market.

The plastic container is seen as a viable alternative to the metal can. However, this does not mean the end of metal cans – or the machinery to seam them. This machinery is adaptable, and with modifications, can seam metal-end plastic cans and all-plastic cans. It appears that conventional seaming equipment will not go obsolete – as long as a container has an end to be seamed.

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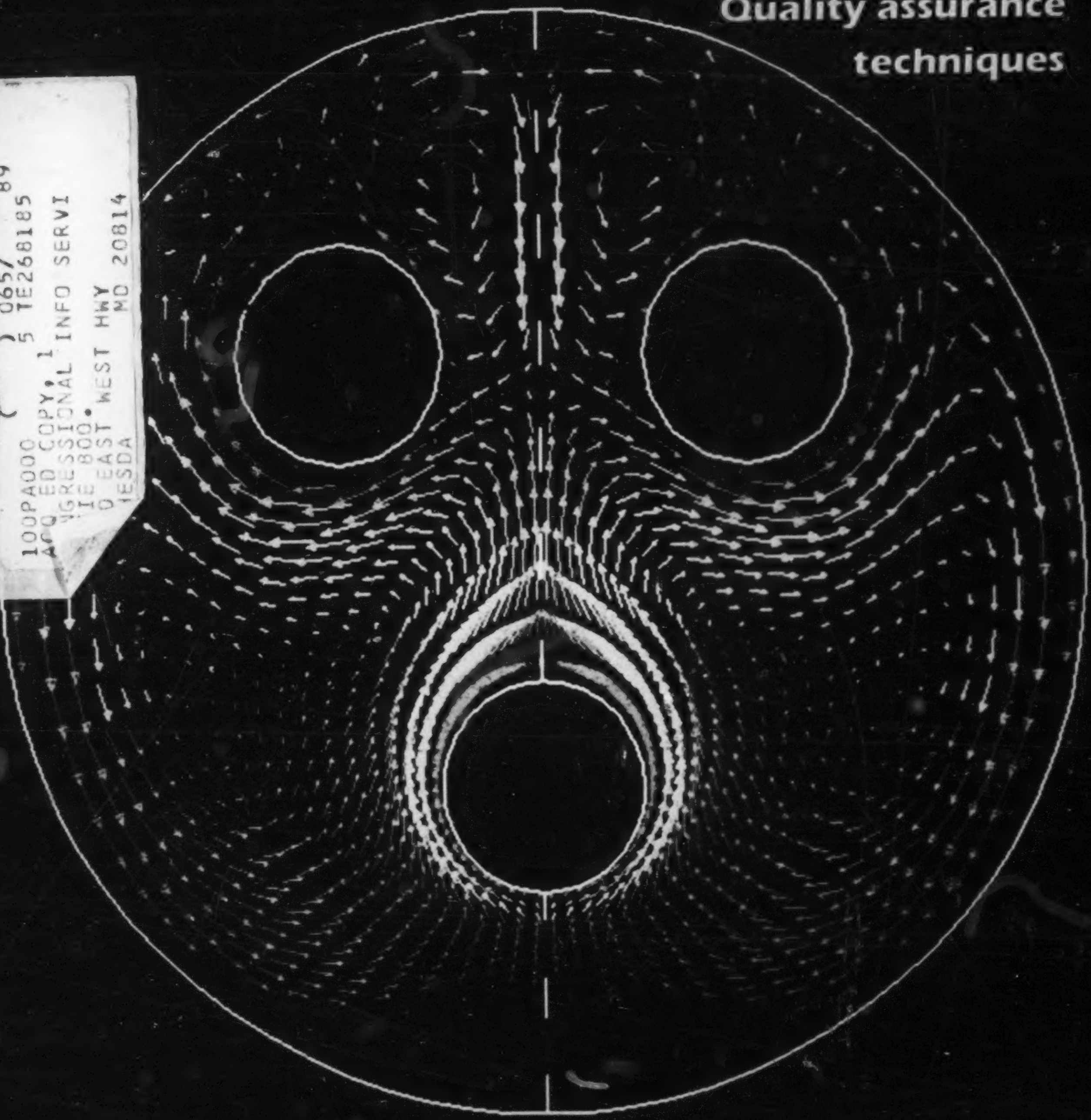

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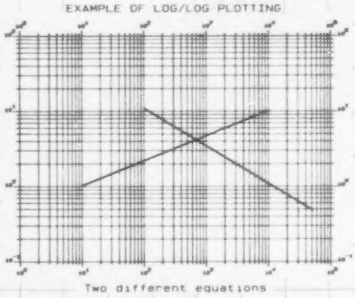

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Robert R. Jones, Editor, *R&D*

R&D's mixed salary bag provides well for workers in some disciplines

Many factors, including early retirement, job changes, mergers, start-ups, and modest pay raises, led to overall gains for the categories of metallurgists, geologists, and biologists, and downers for mathematicians and ceramists, while some individuals moved against the trends.

THE R&D salary bell is going flat. This is not to say that it makes a sour note. (In fact, there are many people among this year's nearly 1,900 *R&D* Opinion Poll respondents who find it especially attractive this way.)

It's just that in any of the recent years a chart of respondents' salaries against the number of persons receiving each salary level would have produced a fairly nice bell curve, a Gaussian distribution, with a distinct peak and almost-matching halves. And each year, as general salary levels were increased to keep even with inflation, the essentially unchanged bell shape moved a little to the right, toward the higher income side of the chart.

Now things are changing. Careful study of the files for this survey shows that, in truth, the shape of the curve has undulated over the years, with this current flattening starting in 1983. But this change was not particularly noticeable until this year's survey.

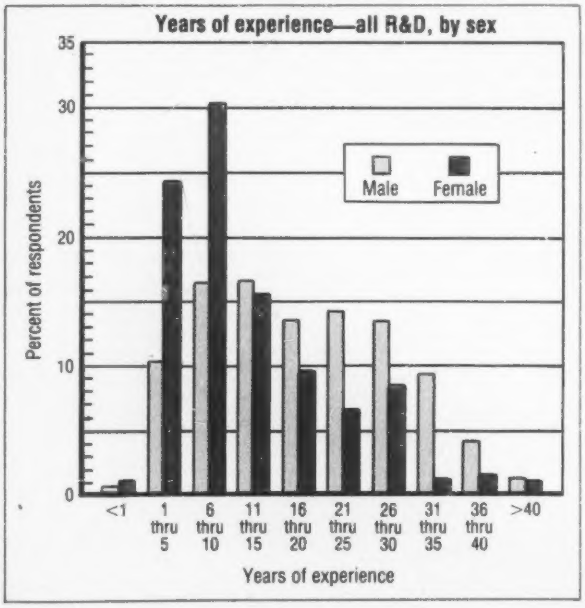
The result is that, for the third year in a row, the peak of the curve has not shifted to left or right. For four consecutive years the salary range of $40,000 through $44,999 has held each year's largest single group of respondents. But the size of that group has dropped from 16.5% of respondents in 1986 to 14.5 this year. The heighth of the plotted peak and the peak's shoulders also are lower.

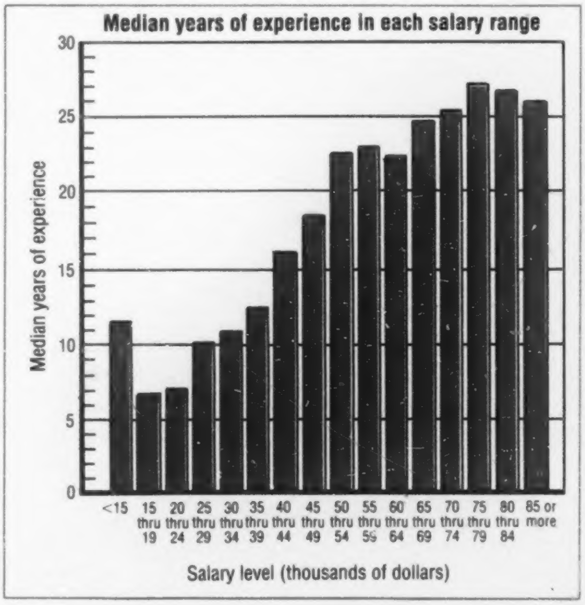
All of those respondents who do not fit under the lower peak now will be found along a stretched out right-hand slope (higher income portion) of the curve.

To be specific, in 1986 60.8% of workers in research, development, and quality assurance who responded to our survey fell into the salary ranges from $35,000 through $59,999. This year, that figure is down to 58.7, a 3.5% decline.

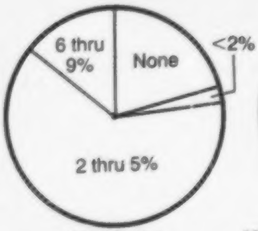
Over the same period, the number in the range above $59,999 has increased from 8.7% to 14.4, a gain of 65% in the affluent portion of the distribution. This has occurred despite the fact that the percentage earning $80,000 per year or more is the same this year as it was last year.

While 46% of respondents received salary in-

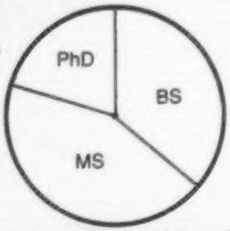

Years of experience—all R&D, by sex


Median years of experience in each salary range

Aeronautical engineer



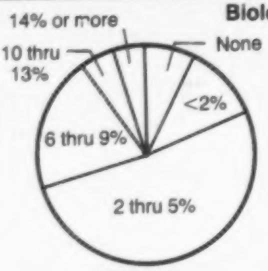
1987 Raise



Highest academic degree (%)

1987 salary range:	<$15,000 = 0.0% >$85,000 = 0.0%	Median $52,917
Years with present employer:	< 1 yr = 0.0% >36 yr = 3.4%	Median 17.0 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 3.6%	Median 49.25 yr
Years of experience:	< 1 yr = 3.4% >40 yr = 6.9%	Median 22.58 yr

Biologist



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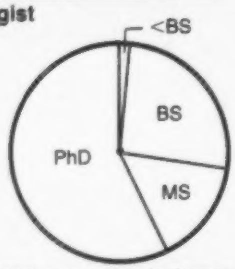
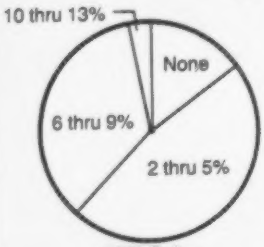


Highest academic degree (%)

1987 salary range:	<$15,000 = 2.2% >$85,000 = 0.0%	Median $40,625
Years with present employer:	< 1 yr = 1.1% >36 yr = 1.1%	Median 9.5 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 0.0%	Median 40.92 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.0%	Median 14.81 yr

Ceramist



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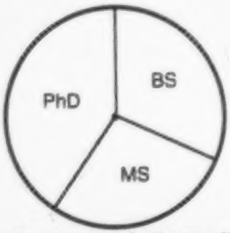
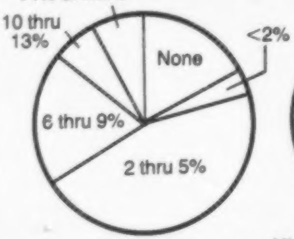


Highest academic degree (%)

1987 salary range:	<$15,000 = 0.0% >$85,000 = 0.0%	Median $43,750
Years with present employer:	< 1 yr = 0.0% >36 yr = 0.0%	Median 8.6 yr
Age of respondents:	<26 yr = 3.4% >65 yr = 0.0%	Median 38.42 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.0%	Median 14.25 yr

Chemical engineer



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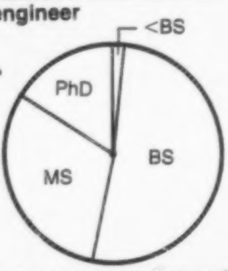
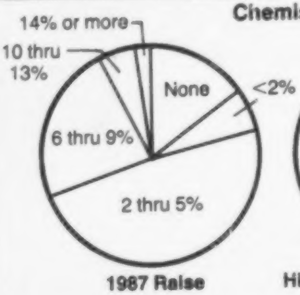


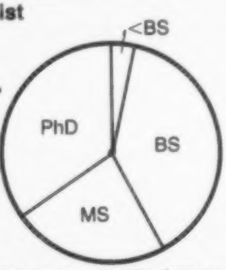
Highest academic degree (%)

1987 salary range:	<$15,000 = 5.3% >$85,000 = 0.0%	Median $45,109
Years with present employer:	< 1 yr = 3.6% >36 yr = 0.6%	Median 8.16 yr
Age of respondents:	<26 yr = 6.5% >65 yr = 0.0%	Median 39.63 yr
Years of experience:	< 1 yr = 1.8% >40 yr = 0.6%	Median 14.07 yr

Chemist



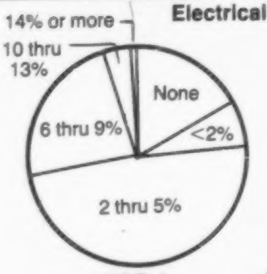
1987 Raise



Highest academic degree (%)

1987 salary range:	<$15,000 = 1.3% >$85,000 = 1.0%	Median $42,113
Years with present employer:	< 1 yr = 5.0% >36 yr = 0.3%	Median 9.83 yr
Age of respondents:	<26 yr = 2.2% >65 yr = 1.4%	Median 41.97 yr
Years of experience:	< 1 yr = 0.3% >40 yr = 1.7%	Median 16.4 yr

Electrical engineer



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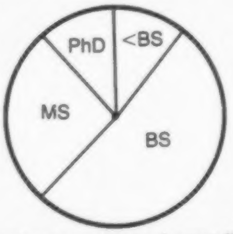
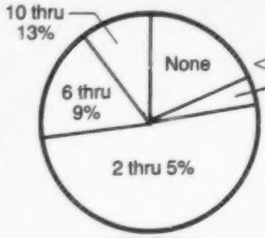


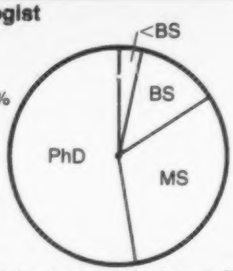
Highest academic degree (%)

1987 salary range:	<$15,000 = 1.3% >$85,000 = 0.6%	Median $45,476
Years with present employer:	< 1 yr = 6.2% >36 yr = 1.9%	Median 9.02 yr
Age of respondents:	<26 yr = 3.1% >65 yr = 1.9%	Median 45.2 yr
Years of experience:	< 1 yr = 0.6% >40 yr = 1.9%	Median 21.45 yr

Geologist



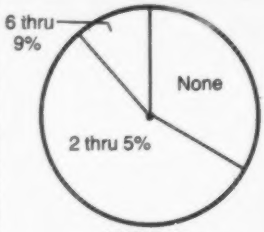
1987 Raise



Highest academic degree (%)

1987 salary range:	<\$15,000 = 6.1% >\$85,000 = 3.0%	**Median** \$48,750
Years with present employer:	< 1 yr = 6.1% >36 yr = 0.0%	**Median** 6.71 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 0.0%	**Median** 44.0 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.0%	**Median** 10.31 yr

Industrial engineer



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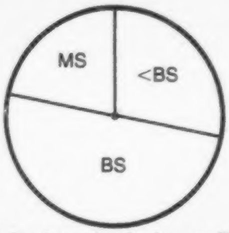
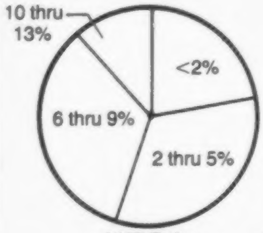


Highest academic degree (%)

1987 salary range:	<\$15,000 = 0.0% >\$85,000 = 0.0%	**Median** \$37,500
Years with present employer:	< 1 yr = 0.0% >36 yr = 5.6%	**Median** 8.75 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 0.0%	**Median** 45.5 yr
Years of experience:	< 1 yr = 5.6% >40 yr = 0.0%	**Median** 18.83 yr

Mathematician



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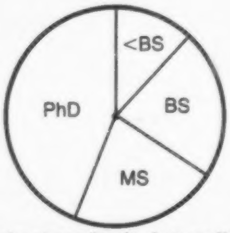
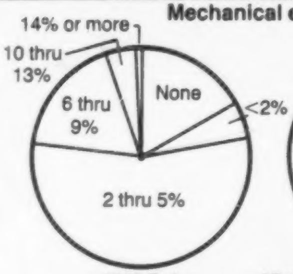


Highest academic degree (%)

1987 salary range:	<\$15,000 = 0.0% >\$85,000 = 0.0%	**Median** \$41,250
Years with present employer:	< 1 yr = 0.0% >36 yr = 0.0%	**Median** 11.75 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 0.0%	**Median** 48.0 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.0%	**Median** 24.25 yr

Mechanical engineer



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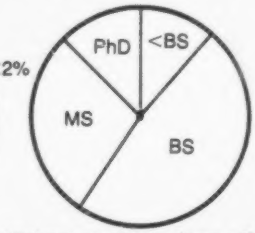
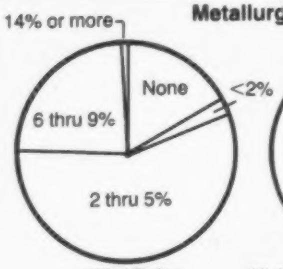


Highest academic degree (%)

1987 salary range:	<\$15,000 = 1.9% >\$85,000 = 0.5%	**Median** \$44,828
Years with present employer:	< 1 yr = 4.3% >36 yr = 1.0%	**Median** 9.11 yr
Age of respondents:	<26 yr = 2.9% >65 yr = 0.0%	**Median** 43.25 yr
Years of experience:	< 1 yr = 1.0% >40 yr = 1.4%	**Median** 18.33 yr

Metallurgist



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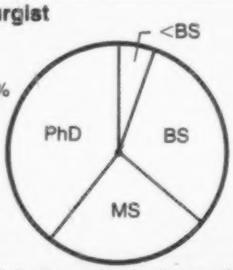
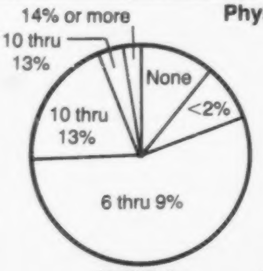


Highest academic degree (%)

1987 salary range:	<\$15,000 = 2.9% >\$85,000 = 0.0%	**Median** \$49,375
Years with present employer:	< 1 yr = 2.9% >36 yr = 0.0%	**Median** 9.04 yr
Age of respondents:	<26 yr = 4.3% >65 yr = 4.3%	**Median** 43.77 yr
Years of experience:	< 1 yr = 1.4% >40 yr = 2.9%	**Median** 18.0 yr

Physicist



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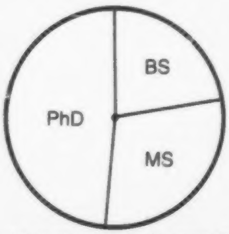


Highest academic degree (%)

1987 salary range:	<\$15,000 = 2.1% >\$85,000 = 1.4%	**Median** \$47,955
Years with present employer:	< 1 yr = 1.4% >36 yr = 0.0%	**Median** 9.5 yr
Age of respondents:	<26 yr = 0.7% >65 yr = 0.7%	**Median** 44.11 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.7%	**Median** 18.1 yr

creases last year (affecting income this year) that were larger than inflation, the median income is little changed from last year's (up 0.4%). This suggests that substantial numbers of higher-paid individuals have left the field through—for example—early retirement. Other parts of this study lead to the same conclusion.

Increases in rate of pay*

Amount of increase	1988	1987	1986	1985	1984	1983
	% of respondents					
None	14.5	16.5	11.3	9.3	16.3	14.7
Less than 2%	6.3	4.3	3.6	2.9	2.1	1.9
2 through 5%	49.8	39.2	37.1	36.6	26.9	15.9
6 through 9%	21.7	30.8	36.3	37.6	38.9	34.2
10 through 13%	4.7	6.0	8.3	10.1	11.5	25.1
14% or more	3.0	3.2	3.3	3.6	4.4	8.3
Ahead of inflation	46.0	79.2	60.1	63.3	54.8	33.4

* Granted in preceding year for year shown

The table shows the distribution and size ranges for salary increases in research, development, and quality assurance from 1983, when inflation was high, to date. Despite the much lower rate of inflation in 1987, the portion of respondents who received salary increases greater than the amount of inflation is at the lowest level since 1983.

Some disciplines show strong indications of changing patterns of employment. Median years of experience can shift for a variety of reasons, but perhaps the fastest effect comes as a result of changes in hiring and retirement practices. Of particular interest this year are the chemical engineers whose median years of experience dropped from 16.0 to 14.1, and the mechanical engineers who dropped from 20.3 to 18.3.

For both disciplines, the percentages of those who have less than one year's experience are up and the percentages having more than 40 years' experience are down, suggesting that early retirees may be being replaced by employes who are new to the fields.

This is supported, too, as the median ages are lower now in these disciplines than they were last year, with chemical engineers down from 41.3 to 39.6 and mechanical engineers down from 45.4 to 43.2.

That the industry is in flux is further borne out in the rankings of disciplines by median salaries. At no other time in recent years has there been so much change in rankings over one year. Five disciplines suffered declines in their median salaries from 1987 to 1988, and all but one of these lost rank in the table. Only one discipline, metallurgists, had a negative in the percent of increase column last year, and they were the third-highest gainer this year.

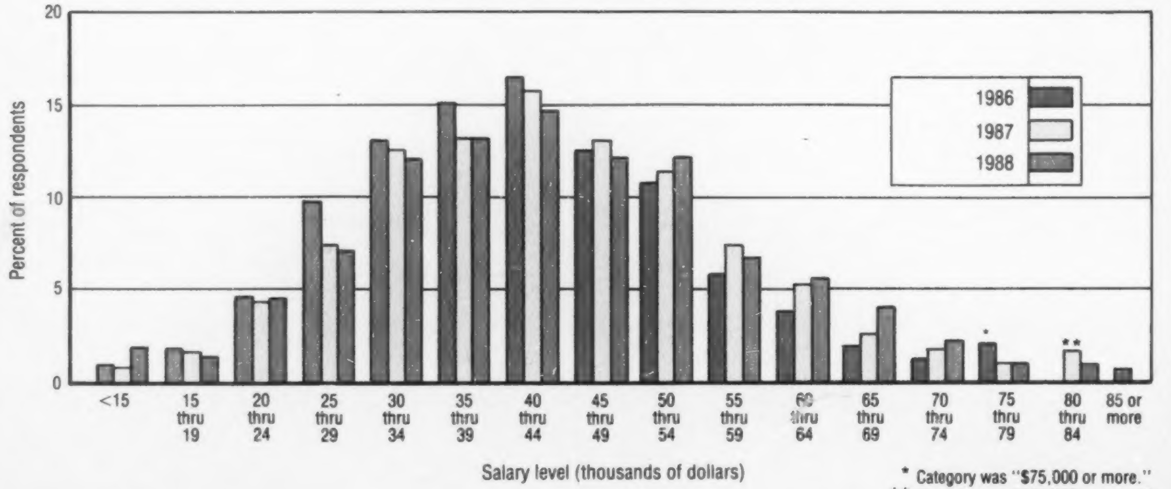
Rankings for disciplines by median salaries

Rank		Discipline	Median salary		% Increase
1988	1987		1988	1987	
1	1	Aero. Engr.	$52,917	$50,278	5.3
2	4	Metallurgist	49,375	46,625	5.9
3	7	Geologist	48,750	45,714	6.6
4	2	Physicist	47,955	48,431	−1.0
5	9	Elec. Engr.	45,476	44,308	2.6
6	6	Chem. Engr.	45,109	45,865	−1.6
7	8	Mech. Engr.	44,828	44,385	1.0
8	3	Ceramist	43,750	47,812	−9.3
9	10	Chemist	42,113	41,860	0.6
10	5	Mathematician	41,250	46,250	−10.8
11	12	Biologist	40,625	38,100	6.6
12	11	Indust. Engr.	37,500	38,889	−3.6

Despite the shifts in discipline rankings, the net movement is (slightly) upward, and the R&D industry remains an attractive demographic market. Scientists and engineers working in research and development will draw a collective paycheck this year exceeding $26.04 billion. This is up from $25.9 billion last year and $24.5 billion in 1986.

In the second part of this annual industry profile we will look into the implications of some of the above conclusions and also report on the money value of advanced degrees in this somewhat topsy-turvy salary situation. We also will examine relative pay scales in research and development for men and women, and the advantages—in salary terms—for jobs in government, universities, and industry. **R&D**

Salary levels for all R&D (3 years compared)



* Category was "$75,000 or more."
** Category was "$80,000 or more."

OPINION POLL RESULTS

Surprise! Staff meetings are worth it

IN THE JULY 1987 issue of *Research & Development* we asked your opinions of staff meetings, fully expecting almost unanimous dislike of meetings regardless of length or purpose. The responses we received from 1,062 readers suggest that staff meetings are needed and, for the most part, are worthwhile.

By far the majority of the meetings are held to present progress reports. Most meetings also last about an hour and are informal. More than 60% of the respondents also feel that the number of meetings they now have is adequate. Results of the survey follow:

1. *How often do you have staff meetings?*

a.	Weekly	37%
b.	Monthly	19
c.	When needed	32
d.	Rarely, if ever	11

2. *In general, are the meetings worthwhile?*

a.	Yes	46%
b.	No	13
c.	Sometimes	41

3. *How long do your meetings last?*

a.	More than an hour	43%
b.	60 min. at most	46
c.	30 min. or less	11

4. *Are the meetings based on a previously distributed agenda?*

a.	Yes	20%
b.	No	50
c.	Sometimes	29

5. *What usually is the main purpose for having the meetings that you attend?*

a.	Scheduling and job assignments	21%
b.	Progress reports, research updating	66
c.	Planning for future research	6
d.	Brainstorming/"blue sky" discussions	5

6. *Would you consider the meetings that you attend to be formal or informal in format?*

a.	Formal	10%
b.	Informal	89

7. *Does someone keep minutes or make a report of what is discussed at the meetings?*

a.	Yes	37%
b.	No	63

8. *How do you feel about the number of meetings that is scheduled for your staff?*

a.	Would like to have more meetings	18%
b.	Would like to have fewer meetings	20
c.	The number of meetings we have now is adequate	61

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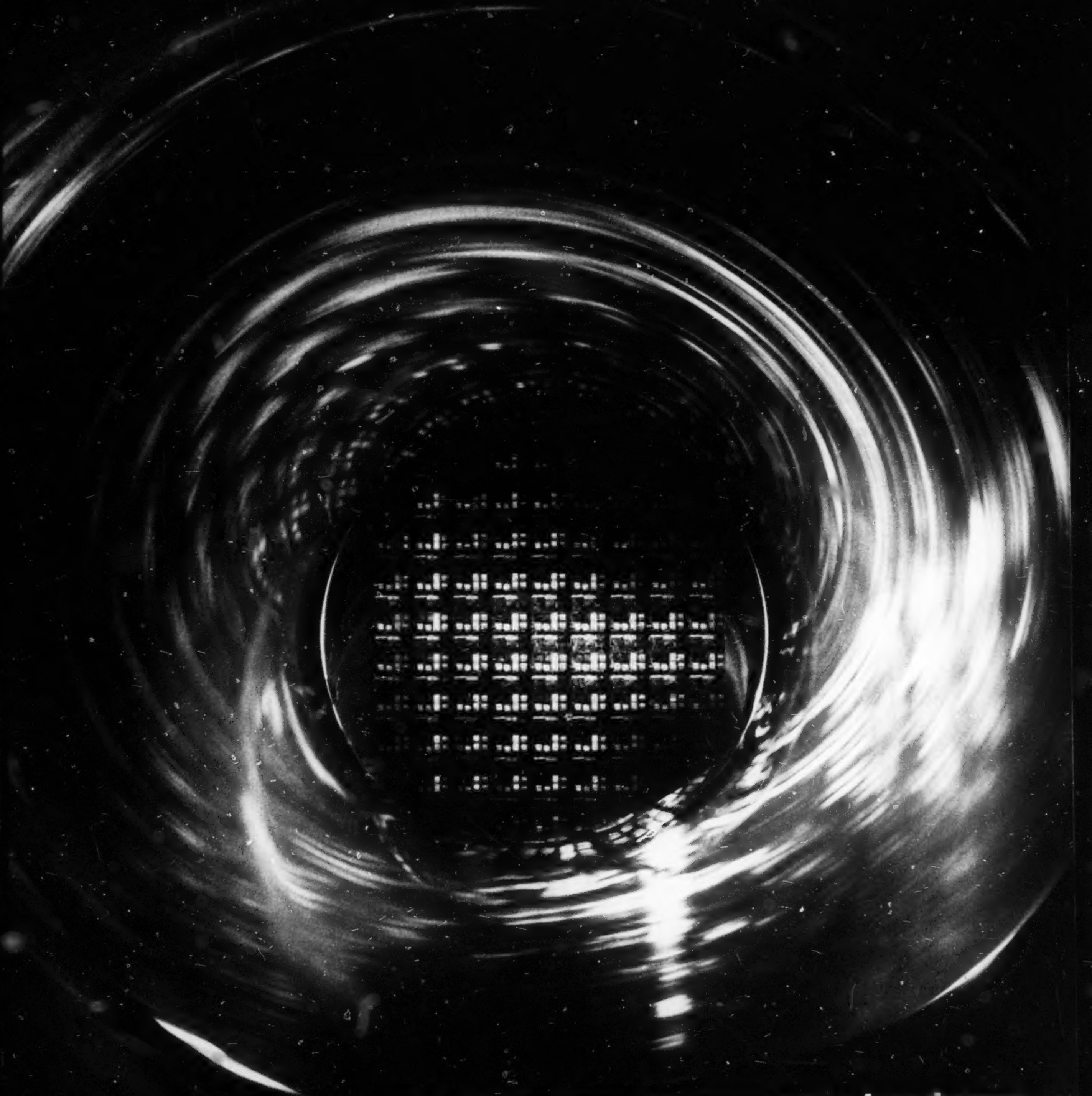

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Does BC stand for "before chips"? Chips like those on this silicon wafer may be the basis for computer hardware in your car, instruments, or memory systems. Photo by General Electric R&D Center.

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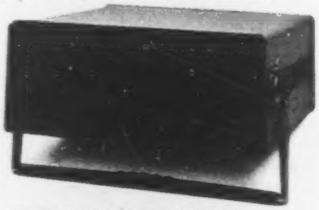

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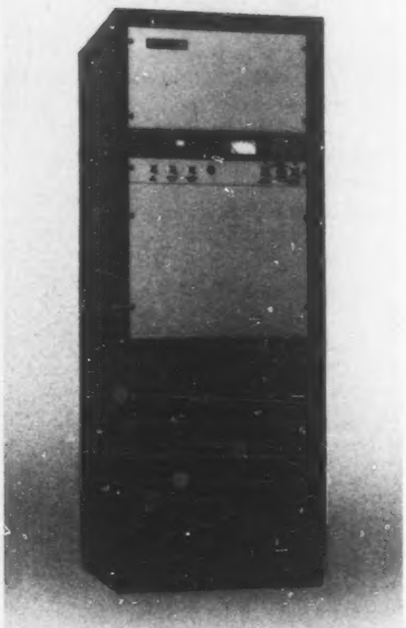

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CIRCLE **104** ON INQUIRY CARD

USE OF ELECTRICAL AND ELECTRONIC INSTRUMENTS

While printer-plotters rank first in both current use and plans to acquire on a total-sample basis, other instruments top them when category-based measures are used.

C.J. Mosbacher
Consultant, *R&D* magazine

OF THE 868 *Research & Development* readers who responded to our most recent Trendsurvey questionnaire, 91.4% currently use at least one type of electrical or electronic instrument or device. In addition, 44.6% plan to acquire one or more within a year. The survey includes 30 categories of electrical/electronic equipment plus a category for "other."

Without the "other" category, which was not included in calculating the numerical data presented in this article, average present use is 26.9% and average plan to acquire is 4.8%. Data for each category of instrument (and equipment) are presented on a total-sample basis in the first bar graph of this article. Detailed data are given in a table that includes a demographic breakdown by the disciplines of the respondents.

The top ten equipment types in current use are printer-plotters, digital voltmeters, digital multimeters, low-voltage dc power supplies, microprocessors, electronic digital thermometers, general-purpose oscilloscopes, time and frequency counters, high-voltage dc power supplies, and frequency generators.

For plans to acquire within one year, the top ten are printer-plotters, microprocessors, data loggers, electronic digital thermometers, digital storage oscilloscopes, digital multimeters, low-voltage dc power supplies, IEEE-488 buses, line conditioners and universal power supplies, and high-voltage dc power supplies. Of the ten categories, six also are included in the top ten for present use.

As previously noted, printer-plotters rank first in both total-sample present use and plan to acquire. Examination of the detailed demographic table shows that printer-plotters rank first in total-sample rankings except in the life-science-or-medicine plan to acquire category. There they rank third, following data loggers and electronic digital thermometers.

Growth rate: another view of the results

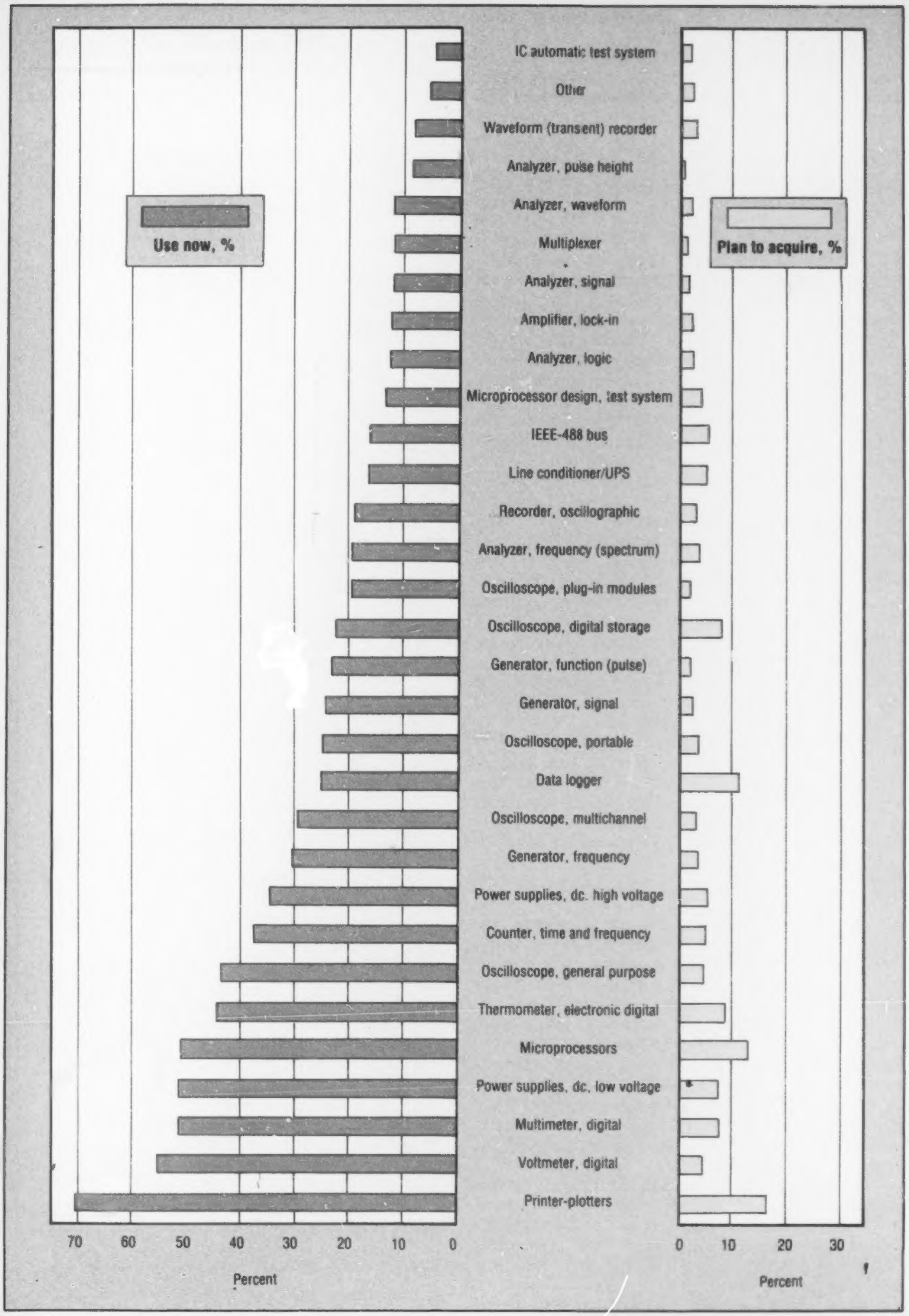
While use now and plan to acquire percentages based on the total sample present the data fairly, they mask an important interpretation of the Trendsurvey data—the growth rate for individual categories.

For example, printer-plotters are used now by 70.3% of respondents and 16.4% plan to acquire them, expressed as percentages of the total of 868 respondents. But by using the 610 respondents who now use printer-plotters as a base by which we divide the 142 respondents who plan to acquire them, we obtain a growth rate of 23.3%. These growth-rate results are presented in the second bar graph and are included in the summary table.

Ranking by total growth rate is shown in the graph. Also shown are rankings from the most recent Trendsurvey of electrical and electronic instruments (*R&D* November 1984, p 114). Possible comparisons of the results of that earlier study will be discussed later in this article.

The top ten rankings in growth rate include only two of those in the total-sample use-now top ten and six of those in the total-sample plan-to-acquire top ten. The average growth rate is 20.0%, which is comprised of 9.4% from present users who plan to acquire and 10.7% from new users (those who did not indicate that they now use that particular instrument but who indicated they plan to acquire it).

The top ten categories of growth rate for present users are: microprocessors, waveform (transient) recorders, data loggers, printer-plotters, microprocessor design and test systems, IEEE-488 buses, digital storage oscilloscopes, line conditioners and universal pow-


Use now, %
Plan to acquire, %
IC automatic test system
Other
Waveform (transient) recorder
Analyzer, pulse height
Analyzer, waveform
Multiplexer
Analyzer, signal
Amplifier, lock-in
Analyzer, logic
Microprocessor design, test system
IEEE-488 bus
Line conditioner/UPS
Recorder, oscillographic
Analyzer, frequency (spectrum)
Oscilloscope, plug-in modules
Oscilloscope, digital storage
Generator, function (pulse)
Generator, signal
Oscilloscope, portable
Data logger
Oscilloscope, multichannel
Generator, frequency
Power supplies, dc, high voltage
Counter, time and frequency
Oscilloscope, general purpose
Thermometer, electronic digital
Microprocessors
Power supplies, dc, low voltage
Multimeter, digital
Voltmeter, digital
Printer-plotters
70
60
50
40
30
20
10
0
Percent
0
10
20
30
Percent

er supplies, electronic digital thermometers and, finally, digital multimeters.

For new users, they are: IC automatic test systems, data loggers, digital storage oscilloscopes, waveform (transient) recorders, line conditioners and universal power supplies, IEEE-488 buses, waveform analyzers, microprocessor design and test systems, frequency (spectrum) analyzers, and logic analyzers.

Demographics: more detail but less reliable

In addition to questions about present use and plans to acquire for each of the 30 instrument categories, respondents were asked to give their job function, employer, and discipline by checking applicable boxes on the reply card. This allowed data for each instrument category to be broken out by demographic group.

Detailed data by primary discipline are given in the summary table. Space precludes detailed discussion of this information. However, averages are given in the following paragraphs.

By discipline, and without the "other" instrument category (as noted earlier this category was not included in any of our calculations), present use averages 33.9% and plan to acquire averages 6.3% for engineering, 22.9% and 3.7% for physical science, and 14.3% and 2.9% for life science or medicine.

By employer, industry averages 25.8% present use and 4.4% plan to acquire, universities 32.4% and 5.6%, nonprofit organizations 26.7% and 4.1%, medical research centers 12.4% and 2.9%, government 28.1% and 4.3%, and other 26.2% and 9.8%.

By job function, corporate officers reported present use as 26.3% and plan to acquire as 9.5%, R&D executives 28.8% and 8.0%, project managers 30.1% and 5.3%, professional staff members 26.3% and 3.7%, and others 24.9% and 3.0%.

While these demographically based data do provide information, they should be used with caution. Statistical reliability suffers when smaller data bases are used, and the number of respondents in some categories such as medical research centers is small. However, the demographic data do allow better comparison with earlier studies.

Historical and other comparisons

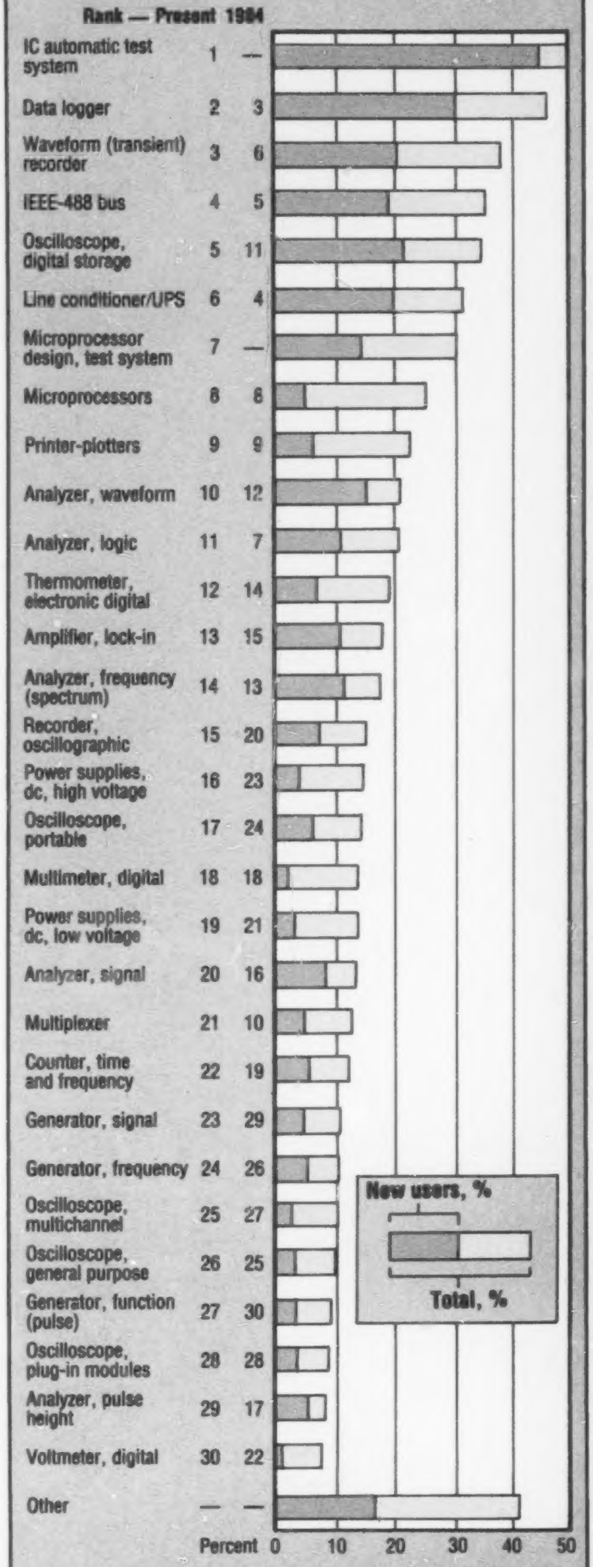
Several factors make it difficult to compare the present results with those of the 1984 Trendsurvey. First are changes in the demographics of the respondents. Second is the fact that only 28 of the categories are the same in both studies.

First, the demographics. Primary disciplines were much the same, with engineers making up 47.4% of the respondents in 1984 and 47.7% now, physical scientists 35.5% versus 34.2%, and life science or medicine 14.4% versus 13.4% now. The difference is that, in 1984, 2.7% of the respondents gave no answer in this category and 4.7% failed to give their discipline this time.

By employer, 53.6% were in industry in 1984 versus 55.9% now, universities 21.3% versus 18.4% now, nonprofit organizations 6.1% versus 3.0% now, medical research centers 3.3% versus 2.1% now, other 14.0% versus 3.8% now, and no answer 1.7% versus 3.2% now.

Government was not included in the 1984 categor-

GROWTH RATE: Plan to acquire / Present use



NOTE: In 1984, Emulator, in-circuit ranked No. 1 and Microprocessor development system (slightly different from the present Microprocessor design, test system) ranked No. 2. Total growth rates were 64.3% and 54.2% respectively.

PRESENT AND PLANNED USE: Data from 868 respondents	Use now								Plan to acquire within 1 year								Growth rate*			
	Total, 868		Engineering, 414		Physical science, 297		Life science or medicine 116		Total, 868		Engineering, 414		Physical science, 297		Life science or medicine 116		Total	Present users who plan to acquire		New users
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	%	No.	%	%
Amplifier, lock-in	107	12.3	45	10.9	50	16.8	6	5.2	20	2.3	7	1.7	11	3.7	1	0.9	18.7	8	7.5	11.2
Analyzer, frequency (spectrum)	172	19.8	117	28.3	42	14.1	5	4.3	31	3.6	21	5.1	6	2.0	1	0.9	18.0	10	5.8	12.2
Analyzer, logic	107	12.3	78	18.8	16	5.4	7	6.0	22	2.5	12	2.9	7	2.4	1	0.9	20.6	10	9.3	11.3
Analyzer, pulse height	73	8.4	36	8.7	29	9.8	4	3.4	6	0.7	4	1.0	2	0.7	0	0.0	8.2	2	2.7	5.5
Analyzer, waveform	100	11.5	68	16.4	23	7.7	2	1.7	21	2.4	12	2.9	5	1.7	3	2.6	21.0	5	5.0	16.0
Analyzer, signal	104	12.0	64	15.5	28	9.4	6	5.2	14	1.6	9	2.2	5	1.7	0	0.0	13.5	5	4.8	8.7
Counter, time and frequency	329	37.9	206	49.8	91	30.6	21	18.1	41	4.7	27	6.5	10	3.4	2	1.7	12.5	22	6.7	5.8
Data logger	218	25.1	130	31.4	58	19.5	19	16.4	103	11.9	62	15.0	23	7.7	13	11.2	47.2	36	16.5	30.7
Generator, frequency	262	30.2	175	42.3	67	22.6	11	9.5	27	3.1	18	4.3	5	1.7	2	1.7	10.3	11	4.2	6.1
Generator, function (pulse)	203	23.4	129	31.2	54	18.2	14	12.1	19	2.2	11	2.7	5	1.7	1	0.9	9.4	13	6.4	3.0
Generator, signal	210	24.2	142	34.3	48	16.2	12	10.3	22	2.5	13	3.1	5	1.7	2	1.7	10.5	12	5.7	4.8
IC automatic test system	40	4.6	27	6.5	10	3.4	1	0.9	20	2.3	15	3.6	3	1.0	2	1.7	50.0	2	5.0	45.0
IEEE-488 bus	142	16.4	84	20.3	51	17.2	5	4.3	50	5.8	30	7.2	17	5.7	3	2.6	35.2	22	15.5	19.7
Line conditioner/UPS	147	16.9	74	17.9	52	17.5	17	14.7	47	5.4	26	6.3	18	6.1	2	1.7	32.0	17	11.6	20.4
Microprocessors	444	51.2	237	57.2	144	48.5	48	41.4	113	13.0	68	16.4	31	10.4	9	7.8	25.5	89	20.0	5.5
Microprocessor design, test system	115	13.2	92	22.2	17	5.7	3	2.6	35	4.0	29	7.0	4	1.3	2	1.7	30.4	18	15.7	14.7
Multimeter, digital	449	51.7	264	63.8	142	47.8	30	25.9	62	7.1	38	9.2	15	5.1	7	6.0	13.8	50	11.1	2.7
Multiplexer	100	11.5	65	15.7	20	6.7	11	9.5	13	1.5	9	2.2	4	1.3	0	0.0	13.0	8	8.0	5.0
Oscilloscope, digital storage	195	22.5	130	31.4	49	16.5	9	7.8	68	7.8	43	10.4	20	6.7	4	3.4	34.9	24	12.3	22.6
Oscilloscope, general purpose	381	43.9	240	58.0	101	34.0	26	22.4	38	4.4	21	5.1	12	4.0	4	3.4	10.0	27	7.1	2.9
Oscilloscope, multi-channel	258	29.7	175	42.3	61	20.5	12	10.3	26	3.0	19	4.6	3	1.0	2	1.7	10.1	19	7.4	2.7
Oscilloscope, plug-in modules	172	19.8	118	28.5	39	13.1	8	6.9	16	1.8	11	2.7	3	1.0	2	1.7	9.3	10	5.8	3.5
Oscilloscope, portable	215	24.8	143	34.5	53	17.8	12	10.3	30	3.5	23	5.6	6	2.0	1	0.9	14.0	15	7.0	7.0
Power supplies, dc, high voltage	301	34.7	153	37.0	114	38.4	22	19.0	45	5.2	29	7.0	11	3.7	3	2.6	15.0	33	11.0	4.0
Power supplies, dc, low voltage	447	51.5	258	62.3	134	45.1	40	34.5	61	7.0	43	10.4	11	3.7	5	4.3	13.6	47	10.5	3.1
Printer-plotters	610	70.3	301	72.7	216	72.7	71	61.2	142	16.4	75	18.1	50	16.8	11	9.5	23.3	98	16.1	7.2
Recorder, oscillographic	165	19.0	105	25.4	37	12.5	16	13.8	26	3.0	23	5.6	0	0.0	3	2.6	15.8	13	7.9	7.9
Thermometer, electronic digital	384	44.2	212	51.2	128	43.1	30	25.9	74	8.5	41	9.9	19	6.4	12	10.3	19.3	44	11.5	7.8
Voltmeter, digital	479	55.2	295	71.3	141	47.5	28	24.1	36	4.1	23	5.6	11	3.7	2	1.7	7.5	27	5.6	1.9
Waveform (transient) recorder	71	8.2	43	10.4	22	7.4	3	2.6	27	3.1	17	4.1	9	3.0	0	0.0	38.0	12	16.9	21.1
Other	51	5.9	19	4.6	16	5.4	15	12.9	21	2.4	8	1.9	7	2.4	5	4.3	41.2	12	23.5	17.6

* Growth rate is calculated by dividing plan to acquire by present use for that particular instrument category.

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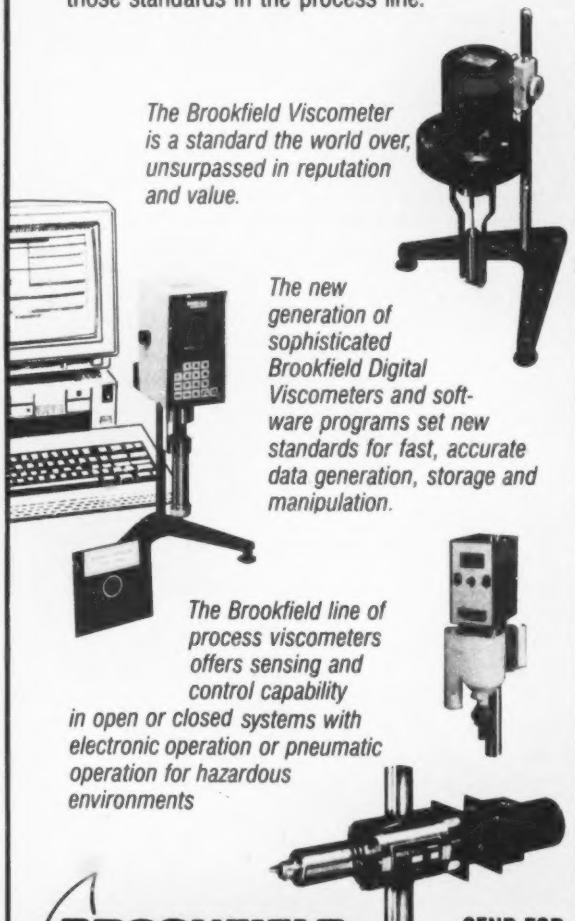

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CIRCLE 264 ON INQUIRY CARD

OPINION POLL RESULTS

Researchers want to do extra, but . . .

IN THE JUNE 1987 issue of *Research & Development* we asked about reader interest in company policies that make it possible for scientists to pursue personal research projects on company time. Of the 700 respondents to the questions, 94% said that they would be interested in doing research other than what is assigned to them, yet only 32% of the respondents work for companies that have such policies.

Of those who work for companies that have personal research policies, 58% have had personal projects result in new products or have improved company processes. It also was encouraging to see that when a personal project results in a worthwhile product, 88% of the scientists are allowed to participate in the product's development. Results of the survey follow.

1. *Are you interested in doing research other than what is assigned to you?*
   a. Yes . . . 94%   b. No . . . 6%
2. *Does your company have a policy that encourages personal research projects?*
   a. Yes . . . 32%   b. No . . . 68%
3. *Would you like to see your company adopt a policy that promotes personal research projects?*
   a. Yes . . . 83%   c. Indifferent . . . 11%
   b. No . . . 2   No Response . . . 3
4. *Would the presence or absence of such a policy be a factor if you were looking for a job?*
   a. Yes . . . 71%   b. No . . . 28%   NR . . . 1%

The remaining questions pertained only to those whose companies have personal research policies.

5. *How much time is provided by your company to pursue personal research ideas?*
   a. 4 hours or less a week 21%
   b. more than 4 hours a week 9
   c. as much time as I want, provided my regular work gets done 58
   d. company facilities are available, but may only be used on personal time 12
6. *What incentive is there to do personal research?*
   a. bonus if a development becomes profitable or improves a company product 16%
   b. additional vacation time, free trips, or some other perquisite 1
   c. there is no incentive other than personal satisfaction, company loyalty, and a desire to advance my position 83
7. *Have any of your personal research projects ever paid off by becoming a product or by improving a process?*
   a. Yes . . . 58%   b. No . . . 40%   NR . . . 2%
8. *Do you have to get approval for a personal project idea from a superior?*
   a. Yes . . . 46%   b. No . . . 54%

⟶

OPINION POLL

Will superconductivity ever be practical?

WE ALL HAVE BEEN bombarded by reports in recent months of developments of superconducting materials with ever-rising transition (T_c) temperatures. Most recently, noted superconductor researcher Paul Chu of Univ. of Houston reported development of a bismuth-based material with a T_c of 114 K.

Newspapers, magazines, and television programs have given extensive coverage to this very exciting research field. In addition, virtually every materials-oriented scientific symposium within the past year has included sessions on superconductor research. Though there is little doubt that someday this research work will bear very important and valuable fruit, we would like to know what the readers of *R&D* think about superconductivity, its potential, and when we will begin to harvest this fruit.

Please answer the following questions on the Reader Service card in the back of this issue. Results of this survey will be reported in a future issue.

1. How long do you think it will be before we begin to see practical, affordable applications for superconductive materials?
   a. 5 years
   b. 10 years
   c. 15 years
   d. 20 or more years
2. What do you think will be the first practical application of these materials?
   a. electric utility plants
   b. motor vehicles
   c. small electric motors
   d. computers
   e. some other application
3. When do you think we will see development of a room-temperature superconducting material?
   a. in 5 years
   b. in 10 years
   c. in 20 years
   d. not in the foreseeable future
4. Is development of a room-temperature superconducting material going to be essential before we will see everyday use of superconductive electricity carriers?
   a. Yes
   b. No
   c. Doubtful
5. Is this a research field that should be heavily funded by tax dollars?
   a. Yes
   b. No
6. Has the popular press generally done a credible job of reporting progress in this field?
   a. Yes
   b. No

Opinion Poll Results continued

9. *If it is decided that your reserach project has resulted in something that is worthwhile, are you allowed to participate in its development into a product?*
   a. Yes . . . 51%
   b. Yes, in a limited capacity . . . 37%
   c. No . . . 8%
   NR . . . 4

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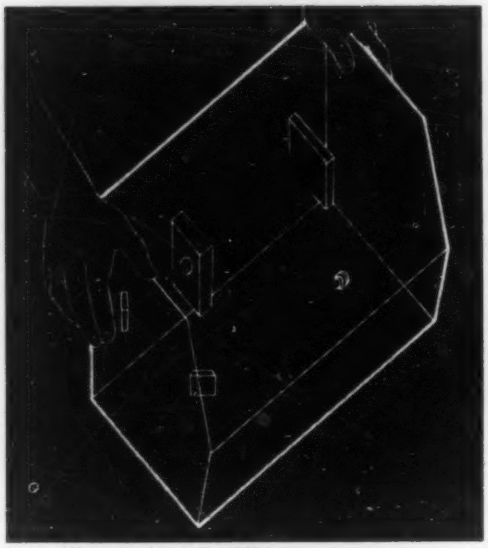

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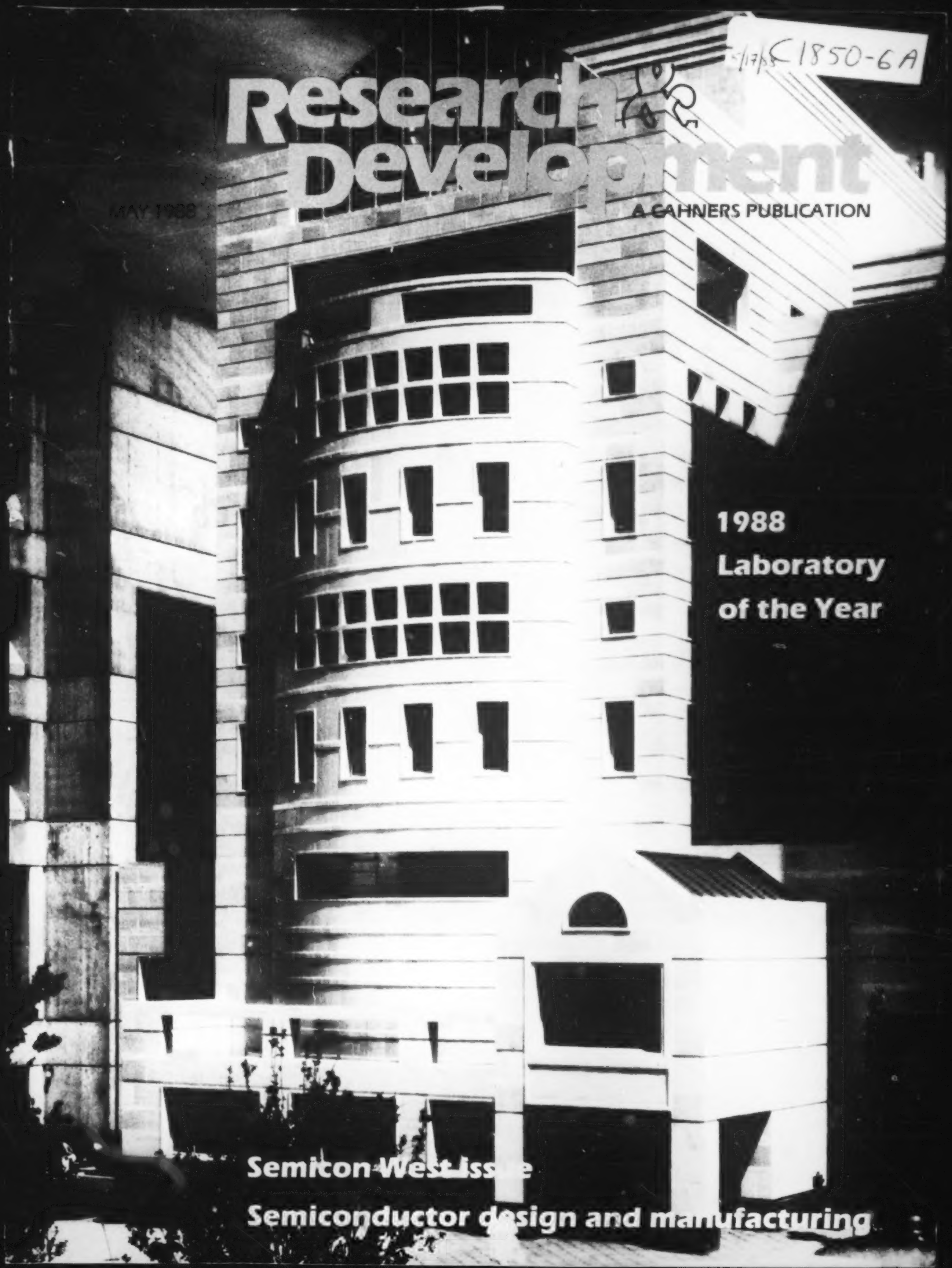

1988 Laboratory of the Year

Semicon West Issue

Semiconductor design and manufacturing

SERVING THE
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Research & Development

The magazine with the
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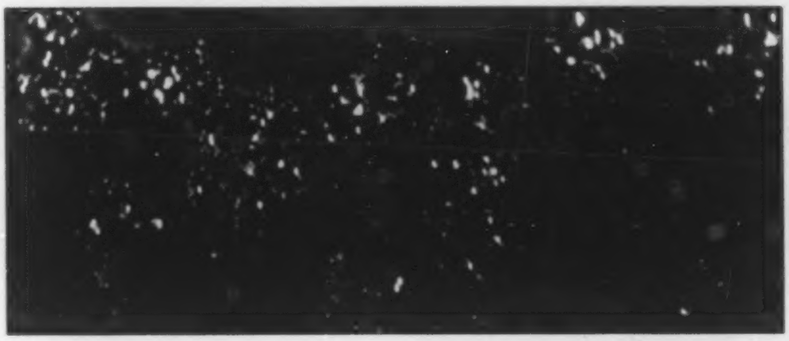
Pseudocolor image for fractal research. See p 92.



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ABOUT THE COVER

Research & Development's 1988 Laboratory of the Year is the Vollum Institute for Advanced Biomedical Research, a research division of Oregon Health Sciences Univ., Portland, OR. Planners designed the facility to be a catalyst for university development and to attract to the staff outstanding biomedical researchers and teachers.

High Honors are awarded to the U.S. Dept. of Energy's High Temperature Materials Laboratory and to the Allied-Signal Inc. Charles W. Nichols Jr. Technology Center. Receiving special mention in this year's competition is the DuPont Experimental Station Bldg. 328.

An article beginning on p 68 describes the 1988 Lab of the Year and the other award-winning facilities.

NEWS

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45 **Computers:** New adder circuit could improve computer speed

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92 **There's more in the picture than meets the eye:** Fred Wetzler, consultant; image-analysis hardware and software can help you get new details from the images offered by your SEM or TEM.

97 **Magnetically confined ECR increases the uniformity of high-density plasmas:** Mike Cooke, Electrotech Equipments Ltd.; ECR plasmas offer low-damage anisotropy and ion-energy controls.

112 **Find wafer flaws with optical techniques:** A. Bivas and R.A. Powell, Varian Assoc. Inc.; optomechanical system provides a nondestructive method for full-wafer maps of properties.

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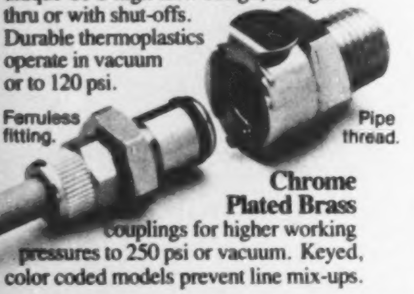

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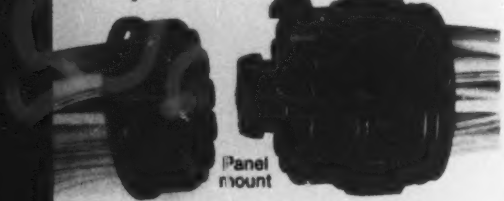

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Robert R. Jones, Editor, *R&D*

R&D industry developing an entirely new look

Changes which appeared as glitches in data several years ago appear to be turning into trends that will develop an entirely new profile for the typical worker in research, development, and quality assurance.

IN THIS second part of our annual profile of the R&D industry (the first part appeared in March), we will look at data which seem to indicate that changes are being made in the profile of the industry—changes other than the usual upward movement of salaries with inflation.

The first article was more general. In this article we will look at some intriguing details. For example, what does it tell us when the proportion of persons responding to this survey who have less than one year's experience has tripled, going from 0.2% two years ago, to 0.4% last year, and to 0.6% this year?

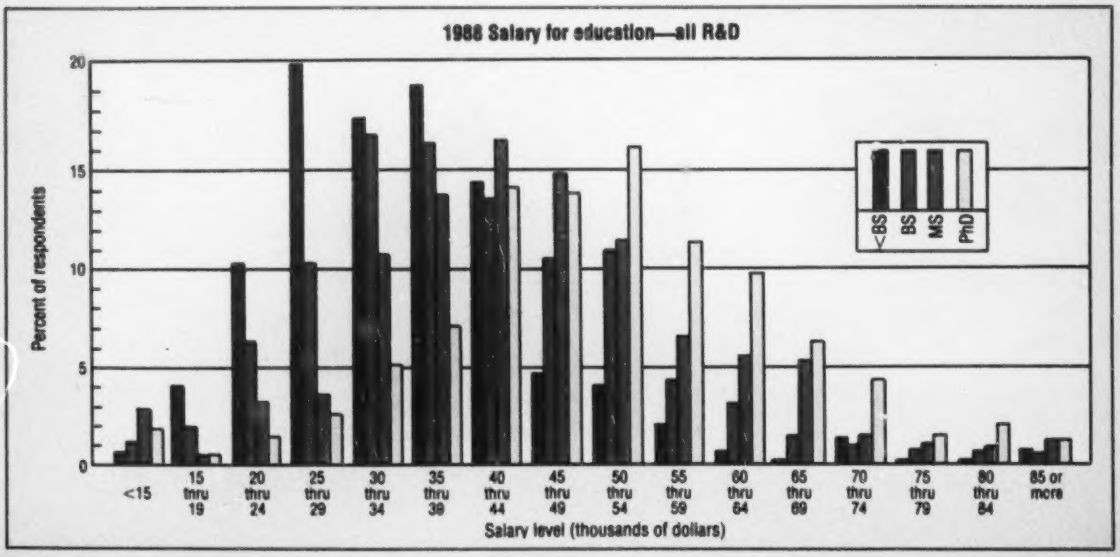
Add to that the fact that those with less than 6 years' experience represented 11.5% of last year's repondents and make up 12.0% this year, an increase of more than 4%. In the same period, the portion of those with more than 35 years' experience declined nearly 21%, having been 6.8% last year and now is 5.4%.

Is it meaningful that the portion who have been with their present employer less than 4 years was 18.1% two years ago and 20.3% last year, and is 21.0% now, an increase of 16%? Or that those earning less than $25,000 per year made up 6.6% of respondents last year and are 7.7% this year, another increase of 16%, and this one in spite of (albeit modest) inflation?

What about the fact that respondents younger than 31 constituted an 11.5% portion in 1986, 12.7% in 1987, and are 13.2% now, an increase of almost 15%? Or that in the past year, the portion older than 55 has declined by nearly 5% from 16.6% to 15.8%?

And finally, how important is it that median salaries for all R&D in our four most-recent surveys of the industry have been 1985, $40,180; 1986, $41,449; 1987, $43,224; and 1988, $43,403? These constitute increases from the preceding years of 6.3%, 3.2%, 4.3%, and 0.42% respectively—a declining rate of increase, no matter how you look at it.

Most of the above changes are small, hardly wor-



thy of mention by themselves, but when there are so many changes happening at the same time, it is hard to say that they hold no significance.

Thus we project an industry with a new profile, only slightly changed from a few years earlier, but still one that is younger, has less experience, has not been with the present employer as long, and is earning a little less in relation to some others than was the case a few years back.

Right now, the people in research, development, and quality assurance make up a strong industry—and there are moves afoot to make the industry even stronger (*e.g.*, formation of the R&D 2000 Committee).

As has been mentioned in other years, this industry pays well for experience, and that was illustrated in a chart in the March issue. Another area that is well rewarded is education. In R&D the premium that is paid for advanced study can be very attractive.

For some reason, perhaps because of early retirement programs, the portion of respondents with PhD degrees in our annual survey has been declining in recent years. After climbing to a high of 33.1% in 1985, the PhD portion dropped to 30.1% in 1986 and 28.0% last year. Now it stands at 29.2%, up more than 4% from a year ago, and in line with figures of the early 1980s.

Biologists have the highest percentage of PhDs at 56.0, up from 52.0 last year and 54.1 the year before. Other PhD percentages are geologists 51.5, physicists 49.0, mathematicians 44.4, ceramists 41.4, metallurgists 40.0, chemists 35.3, aeronautical engineers 21.4, chemical engineers 16.6, electrical engineers 11.8, and mechanical engineers 11.5.

When it comes to advanced degrees, masters plus PhD, geologists lead the way with 84.8% having a PhD or MS. They have displaced physicists from the top position. Other precentages for advanced degrees are physicists 77.6, biologists 72.5, ceramists 69.0, mathematicians 66.7, metallurgists and aeronautical engineers tied at 64.3, chemists 57.2, chemical engineers 47.3, mechanical engineers 42.1, electrical engineers 37.9, and industrial engineers 22.2.

Advanced degrees pay dividends

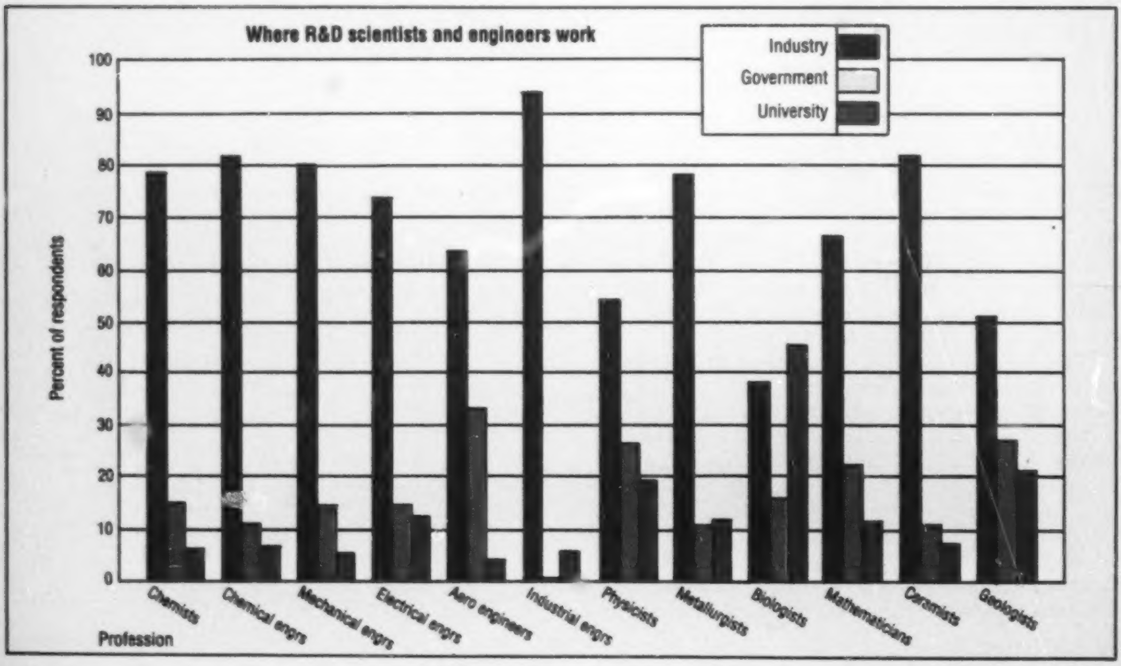
Entirely separate from the personal satisfaction and career advancement that the added education can provide, there is a definite monetary incentive for workers in R&D and QA to go for the higher education.

The research and development scientist or engineer with a doctoral degree can expect a career income advantage of almost $2 million over his colleague who did not go beyond a bachelor degree. At $1,912,000, this figure is up 12.3% from last year's $1,703,000. The figure was $620,000 in 1984.

These, of course, are averages for all of R&D, and the net value for a PhD over a BS depends on an individual's field of endeavor, sex, and whether the employment is in government, university, or industry. Considering the many variables, it is easy to see that many PhDs will reap even greater benefits from their doctorates.

The $2-million-career advantage is what remains after deducting the costs of the added education and allowing for the additional years spent attending classes while the non-PhD was already in the work force. It is assumed that the PhD will work for 35 years after getting the degree, a figure that is supported by the number of respondents who have 35 or more years of experience.

Using similar calculations with different allowances for earning years and expenses, and plugging in the appropriate reported incomes, produces a career advantage figure of $1 million for the PhD over MS de-


Where R&D scientists and engineers work

grees. This is approximately the same as last year's figure.

When the question arises of going to college and getting a degree, the answer is simple. The career advantage of a baccalaureate degree over no degree is just over three quarters of a million dollars, not bad pay for the first few years out of high school!

It's like earning $465,000 a year

And for the individual with a BS who may be considering a masters program, think big. The difference has increased over last year's and now stands at $930,000, or something like a $465,000 advantage for each year in the masters program. At $930,000, this is up more than 30% from two years ago and up by a factor of 2.7 in four years.

From the beginner's standpoint, looking at college, the potential career advantages, in addition to the BS mentioned above, are MS over less than BS, $1.8 million and—the really big jump—PhD over no degree, $2,662,000 (up 7.3% from last year). This latter advantage works out to being paid $300,000 above expenses for each year spent getting a doctorate.

There are other conclusions that can be drawn from the data about highest academic degree and salaries, as shown in the following table.

R&D salaries compared by academic degrees

Degree	Median salary 1988	Median salary 1987	Percent change	Annual difference* 1988	Annual difference* 1987	Difference change (percent)
Doctorate	$50,955	$50,396	+1.1	$6,350	$6,449	−1.5
Master	44,605	43,947	+1.5	5,537	4,313	+28.4
Bachelor	39,068	39,634	−1.4	4,837	4,986	−2.9
<Bachelor	34,231	34,648	−1.2			

*Difference above next lower degree

In recent years, we have made numerous mentions in this annual report of the discrepancies in salaries for men and women and of the many reasons why some differences are justified. In this year's survey, most of the trends continue unchanged, and one result is that male-female salary and benefit differences are getting smaller.

Premiums continue to be paid for years of experience and longevity with the same employer. The culture of the Anglo-Saxon countries makes it proportionately much more difficult for a woman than a man to acquire long years of technical career experience and to stay for 20 or 30 years with a single employer.

The two charts which appeared on page 57 in the first part of this article (March issue) show—in the first one—how the women respondents to this survey fall far behind the men in years of experience, and—in the second—how highly correlated are experience and salary. Those individuals, either male or female, who have large numbers in years of experience almost always have high numbers in the salary columns.

Exceptions or variations from the above generalization are caused by both sex and workplace (*i.e.*, whether you work in industry, government, or university).

Workplace differences changed substantially a few years ago when industry became the best payer, following several decades when it was a given that people who worked for the government received higher pay than they would if doing the same work for other employers. Industry now is the clear pay leader and—this year—government is only slightly ahead of university.

Median salaries all R&D by workplace

	1988	1987	1980
Government	$41,786	$42,200	$29,733
Industry	44,175	43,887	28,354
University	40,250	38,621	25,685

Sex and workplace trends are borne out in the following table of median salaries. As mentioned above, government rate of pay is losing ground in comparison to industry and university. Thus it is not surprising that median salaries for men in government show a decline from last year's.

And despite all of the problems that remain in the areas of equal treatment for women, the R&D industry is doing some catching up in salaries. In this year's survey results, the smallest percent of salary increase for women is larger than the largest for men.

Having said that, we must also acknowledge that the highest median salary for women (women in industry), remains below the lowest for men (men in universities) by 17.1%.

Median salary by sex and workplace

	1988	1987	% change
Men in industry	$45,111	$44,636	+ 1.1
Men in government	42,667	43,239	− 1.3
Men in universities	41,635	40,521	+ 2.7
Women in industry	35,543	34,437	+ 3.2
Women in government	33,500	30,000	+11.6
Women in universities	27,083	24,318	+11.4

Median salaries are determined by annual increases in rate of pay, and it is clear that women dominated that area last year (salary changes last year that determine rate of pay this year). As shown in the following table, almost half (49.6%) of this year's women respondents to our survey reported annual salary increases of 6% or more. This compares to only 39.3% of the men who received such increases.

Percent receiving R&D salary increases by sex

Granted in Amount of Increase	1986 Male	1986 Female	1987 Male	1987 Female
None	16.8	12.8	14.5	14.1
Less than 2%	4.4	3.1	6.6	4.0
2 through 5%	39.6	34.4	50.1	46.3
6 through 9%	30.3	37.8	21.3	24.9
10 through 13%	6.0	6.9	4.6	6.2
14% or more	3.0	4.9	2.9	4.5

Complete results of the survey appear in an accompanying table. **R&D**

1988 R&D industry profile:

1. What is your annual salary?

a.	Less than $15,000	1.9%
b.	$15,000 to $19,999	1.3
c.	$20,000 to $24,999	4.5
d.	$25,000 to $29,999	7.1
e.	$30,000 to $34,999	12.1
f.	$35,000 to $39,999	13.2
g.	$40,000 to $44,999	14.5
h.	$45,000 to $49,999	12.1
i.	$50,000 to $54,999	12.1
j.	$55,000 to $59,999	6.8
k.	$60,000 to $64,999	5.6
m.	$65,000 to $69,999	3.9
n.	$70,000 to $74,999	2.1
o.	$75,000 to $79,999	1.0
p.	$80,000 to $84,999	1.0
q.	$85,000 or more	0.8

2. Your raise during the past year was

a.	None	14.5%
b.	Less than 2%	6.3
c.	2 through 5%	49.8
d.	6 through 9%	21.7
e.	10 through 13%	4.7
f.	14% or more	3.0

3. How long have you worked for your present employer?

a.	Less than 1 year	4.0%
b.	1 through 3 years	17.1
c.	4 through 6 years	16.8
d.	7 through 9 years	13.3
e.	10 through 12 years	10.2
f.	13 through 15 years	6.9
g.	16 through 18 years	6.2
h.	19 through 21 years	7.1
i.	22 through 24 years	6.4
j.	25 through 27 years	4.5
k.	28 through 30 years	3.2
m.	31 through 33 years	2.4
n.	34 through 36 years	1.2
o.	More than 36 years	0.8

4. What is your age?

a.	Under 26 years	2.5%
b.	26 through 30 years	10.7
c.	31 through 35 years	14.2
d.	36 through 40 years	17.4
e.	41 through 45 years	14.0
f.	46 through 50 years	13.6
g.	51 through 55 years	11.7
h.	56 through 60 years	10.5
i.	61 through 65 years	4.2
j.	Over 65 years	1.1

5. How many years of experience do you have?

a.	Less than 1 year	0.6%
b.	1 through 5 years	11.4
c.	6 through 10 years	17.8
d.	11 through 15 years	16.7
e.	16 through 20 years	13.1
f.	21 through 25 years	13.6
g.	26 through 30 years	12.8
h.	31 through 35 years	8.4
i.	36 through 40 years	4.0
j.	More than 40 years	1.4

6. What is the highest degree you hold?

a.	Less than bachelor	7.8%
b.	Bachelor	38.3
c.	Master	24.7
d.	Doctorate	29.2

7. What is your profession?

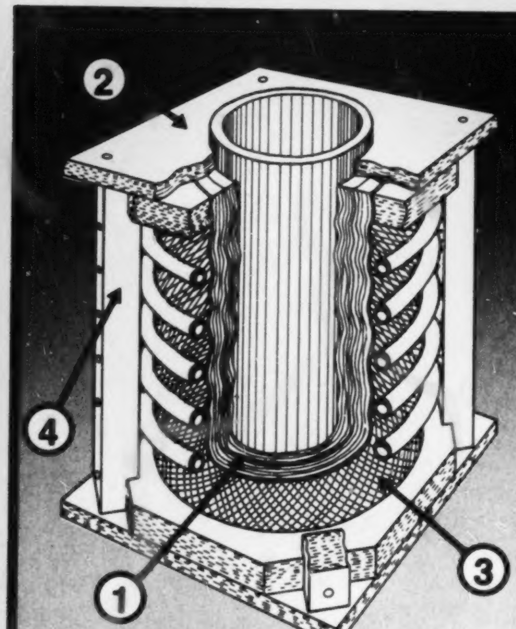
a.	Chemist	36.9%
b.	Chemical engineer	9.0
c.	Mechanical engineer	11.1
d.	Electrical engineer	8.5
e.	Aeronautical engineer	1.5
f.	Industrial engineer	1.0
g.	Physicist	7.6
h.	Metallurgist	3.7
i.	Biologist	4.9
j.	Mathematician	0.5
k.	Ceramist	1.5
m.	Geologist	1.7
n.	Other	12.0

8. Do you work in

a.	Industry	73.3%
b.	Government	15.7
c.	University	11.0

9. Are you

a.	Male	90.4%
b.	Female	9.6



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PHOTOGRAPHIC IMAGES, especially in optical or electron-beam photomicrographs, contain a lot more information than the human eye can discern. Fortunately, digital image-analysis equipment has revolutionized the extraction of information from images of both solid and particulate materials.

Today's application-specific image-analysis software packages make it easy for users to perform many types of complex analyses. Advances in digital image-analysis technology include coupling scanning and transmission electron microscopes (SEMs and TEMs) with backscattered-electron detectors and energy-dispersive x-ray spectrometers.

Since they no longer are confined to optical microscopy image analysis, where spatial resolution is limited to about 3 μm, digital image microanalyzers now can take advantage of the high magnification capabilities of SEMs, TEMs, and scanning transmission electron microscopes.

Images in data base

For example, you can use your SEM image analyzer for R&D or for industrial-process investigation to collect, analyze, correlate, and store image data. You, then, can extract from your data base information from stored images or from morphological or object-classification files previously stored for reference.

In one such application, you might mount a backscattered-electron detector on an SEM. You then can perform image microanalysis of a specimen by grey-level segmentation. The data obtained are directly related to the average atomic number of each element in the sample surface.

The addition of an energy-dispersive x-ray spectrometer (EDS) stage to an SEM can provide a means for directly correlating chemical classification data with morphological data, such as particle size, shape, aspect ratio, and other statistically derived data.

These capabilities, then, open a large realm of possibilities for investigation. Some of the areas of recent interest are the study and analysis of geological samples, air-pollution components, composite and ceramic materials, manufactured and natural fiber configurations, food contaminants, aerosols, submicrometer features of semiconductor devices and materials, microorganisms, and biomedical cell-pathology investigations.

Many image-analysis systems now use nondestructive testing (NDT) techniques to control complex laboratory procedures or manufacturing processes. Still other systems use NDT procedures off-line to aid in the assurance of product quality.

Highly magnified images

As researchers gained experience with digital imaging techniques, they found that a common set of techniques often could be used for many widely different analytical applications. For this reason, digital image analysis is becoming an important concept for NDT and quality assurance labs in materials science,

A COMPUTER-GENERATED pseudocolor image derived from a Mandelbrot number set shows the versatility of the computer as well as the high resolution obtainable in the displays of the image analyzer. In addition, an analyzer can make critical-dimension measurements from either a live or an acquired scanning electron microscope or optical microscope image. (Photos—Tracor Northern, Madison, WI.)

biomedical, and industrial studies. And combining digital image analysis with sophisticated numerical analysis routines offers versatile microanalytical tools for R&D in these fields.

One area that requires such critical high-resolution, high-magnification image analysis is in-process inspection of semiconductor wafers and submicrometer-scale masks for voids, pits, and contaminants among the features on the surface.

The submicrometer world of ultrahigh-speed integrated circuits (UHSIC) is here. Nevertheless, the image-analysis engines needed to measure and inspect the submicrometer features are yet to come. Semiconductor manufacturers expect, however, that within three years, image-analysis techniques will have been developed to meet the demand.

Already, practical applications for image analysis exist in a number of major technical fields. Here are a few examples.

Metallurgical analysis

Digital image analysis has been useful in metallurgy for investigating and classifying raw-material properties and for in-process NDT and quality assurance applications for both raw materials and finished products.

☐ Measurement and analysis of the inclusions in steel yield information that can indicate how readily machinable the steel will be. Image processing permits grey-level discrimination between sulfides and the steel matrix. Globular inclusions of manganese sulfide can be measured by image analysis.

☐ Analysis of the phase composition of processed raw materials can determine the relative proportions of different phases and components. This information lets the researcher predict physicochemical behavior in a furnace, for example, and allows assessment of the potential of a given sample for various uses.

☐ Determining grain size, shape, and orientation provides an indication of end-use properties and per-

SEM image-analysis equipment installed worldwide

	Microscopes	Image-analysis systems
1987	10,000 to 15,000	1,500 to 2,000
1990	11,740 to 17,610	3,690 to 4,920
Gain/yr	5.5%	35%

mits making up quality assurance charts for specific drawing applications or for expected properties of grain-oriented steel.

☐ Emerging metallurgical applications include fractal analysis for characterizing materials by their fractal dimension (Mandelbrot, B.B., *Form, Chance, and Dimension*, Freeman & Co., San Francisco, 1977).

Analysis of ceramics and composites

Ceramics and composites are multiphase materials in which each phase has a specific function and contributes a specific set of properties. For such a material, image analysis can provide a wealth of pertinent information.

For example, in a fiber/matrix composite such as glass-fiber-reinforced polyester resin, image analysis can determine the uniformity of spacing between fibers as well as the orientation of the fibers and the degree of fiber packing.

In addition, the composition of the individual phases is important. Other critical information obtainable by image analysis is the void count—the number and size of voids and the area that voids occupy relative to the total surface area.

For ceramics, a manufacturer needs to know the porosity, the grain size, the distribution and quantity of additives, and the oversize-grain count. Image analysis can provide this information.

In textile fibers, digital image analysis can obtain information on the fiber shape, the location and severity of bends and kinks, fiber surface area, number of fibers/unit area, and the number and size of holes.

Biomedical analysis

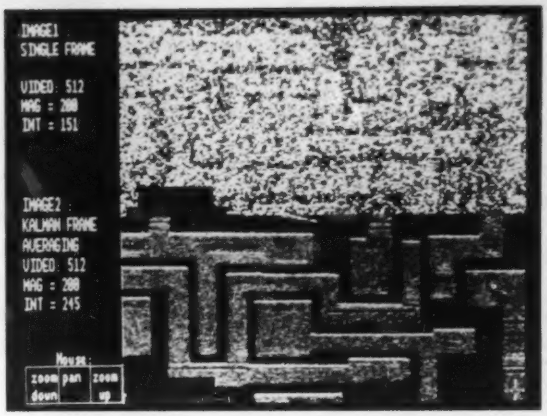
Pathological problems of our aging population are requiring more and more analytical clinical testing. For these tedious manual procedures in, say, multiple-field tissue biopsies, the present practical limit of 100 tests/day in a single lab is inadequate to meet increasing demands. To speed up this type of testing, with equal or better resolution, compared to manual techniques, the field of digital image analysis is about to enter a period of rapid application growth.

Digital image analysis also can address other areas that are putting demands on clinical testing labs. One of the needs is the acceleration of information throughput—getting answers faster than is possible by manual methods.

Other areas include the detection of abnormal cells by rudimentary pattern recognition, the need to communicate clinical data to and from hospitals' host computers, the capability for the clinician to interact with the data system (*i.e.*, to enter information into a data base, to update information in the data base, and to act on data received from both the data base and experimental results), and a facility for storing x-ray picture data in a computer-retrievable data bank.

Major areas in which image analysis already is a strong factor are chromosome kerotyping and the analysis of cells and nuclei to detect the presence of cancer.

In addition, several emerging biomedical applications are relying heavily on image analysis. These include such varied areas as sperm imaging to determine fertility or infertility, immunofluorescence imaging, analysis of bone fragments to determine host signature, bone growth studies, dentistry, surface chemistry to determine lung surfactants, neuroscience, and studies on food contaminants and infestations.



THE UPPER IMAGE shows a single-frame acquisition from an uncoated integrated circuit. The lower image shows the improvement available, using Kalman averaging.

Environmental applications

Digital image analysis can simplify characterization of features and analysis of particles. For this reason, this has become the principal investigative technique in environmental research. Problems addressed include the determination of the particle content of aerosols, ocean samples, atmospheric dust, and filtration products.

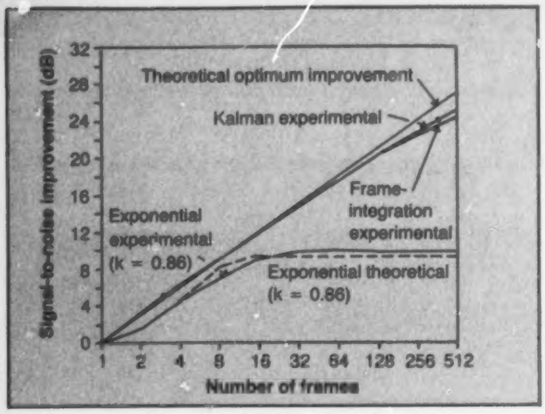
Geological imaging analysis, on the other hand, is primarily concentrated on measurement of features, morphology, the occurrence and identification of phases and elements, and the determination of the composition of minerals and other mixtures of materials. For example, typical investigative applications would include the study of air pollutants and atmospheric transport of particulate matter. Likewise, studies of particulate inclusions in biological tissue and of heavy metal occurrences in the environment also are gaining in importance.

Other researchers are using image analysis to obtain data on locked *vs* liberated mineral compositions, the occurrence of useful minerals in ocean mining operations, exploration for petroleum, the amounts and types of particulates in automotive exhaust, and in solving problems in forensic science. In addition, image analysis can give useful information in the detection and identification of precious metals such as gold in mineral matrices.

At present, the lack of adequate baseline standards for geochemical parameters is hindering the growth of image analysis as a tool for environmental research. As a stopgap measure, individual imaging-equipment vendors provide proprietary data bases for chemical definition.

Molecular modeling

Often described as a computer-graphic "Tinker Toy," molecular modeling is an emerging technique that can present on a CRT screen many of the structur-



USING KALMAN AVERAGING, the signal-to-noise ratio continues to improve with additional frames. Exponential averaging stops improving after 16 frames.

al concepts that chemists formerly had to draw by hand. For example, a modeling program can simulate molecular interaction and plot molecular changes.

A program also can display molecular conformal twisting, interatomic distances, and molecular-surface volume, and it can generate on the screen bimolecular complexes, whether or not anyone has actually made them in a laboratory.

In general, molecular modeling is to molecular analysis and design what three-dimensional solids modeling is to mechanical computer-aided engineering. That is, molecular modeling helps scientists make intelligent decisions about materials, how to make them and, in some cases, which ones to make. The techniques also permit scientists to perform interactive testing of hypotheses.

Major applications for molecular modeling include the design of improved drugs, the study of mutant cells, crystallography, polymer synthesis, protein modeling and engineering, and materials science. A significant future application is auto-docking, or computer-calculated molecular binding, a "fast-track" method for synthesizing and marketing drugs.

Digital image analysis in the future

To get an idea as to where the digital image-analysis industry is heading, our consulting group interviewed a number of industry executives and obtained information from several industry forums. These efforts led to the conclusion that, within the next two years, the field will undergo a 35 to 40% growth.

Several trends already are evident. Among the most significant are:

☐ Use of image analysis in process-control operations, nondestructive testing, and materials quality assurance in the manufacturing plant.

☐ Application of industrial x-ray NDT and EDS imaging is growing as industrial workers perceive that the operating environment can be made safe.

☐ Medium-cost ($25,000 to $30,000) special-application, no-frills image-analysis systems are beginning to establish their own place between low-end, personal-computer-based systems ($15,000 to $35,000) and high-end, general-purpose ($60,000 to $90,000) systems.

☐ More and more often, microscope vendors are providing image-analysis systems as add-on options.

☐ Both the size and the cost of image-analyzer systems is continuing to decline. Within the next three or so years, system cost will decrease another $5,000 to $7,000, while the performance is increasing.

☐ There is, at present, a continuing rapid increase in the availability of application-specific software that performs complex analyses, automates data analysis, and aids in decision making.

☐ True-color imaging will become available on low-cost systems, where it has, until now, been an expensive add-on item.

☐ Increasing use of SEM and x-ray dispersive spectroscopy in biomedical, materials, and particle characterization is generating new demands for rapid, economical, high-resolution image analysis.

☐ The demand to automate entire analysis procedures in quality assurance facilities and to integrate these analyses with process-control computers continues to increase.

☐ Once SEM facilities are integrated with submicrometer-scale semiconductor production lines in 1988 and 1989, the need for image analysis in these applications will increase.

Thus, the recent improvements in image-analysis equipment and in the techniques for applying it are, indeed, making it possible for scientists and engineers to see details never before seen. From this new information, manufacturers can be sure that the products they sell will do the jobs for which they are intended.

Industrial hygienists can learn what hazards may be present in the environment—and how best to deal with them. Biomedical researchers can quickly decide among competing structures of drugs to combat disease. And industrial R&D people can take advantage of the information now available to improve their processes and design new chemical structures for maximum usefulness in practical applications. **R&D**

Reader Response Panel

Please help *Research & Development's* editors serve you better by rating your interest in this article on the Reader Service Card.

High **377** Medium **379** Low **381**

THE AUTHOR

Fred U. Wetzler is a consultant who specializes in writing and editing technical articles for trade journals and aiding in the preparation of high-technology corporate, engineering, and service publications. He formerly wrote a monthly column, "Washington Trends," for *Research/Development*, one of the forerunners of *Research & Development* magazine.

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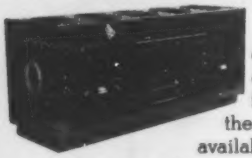

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OPINION POLL RESULTS

Few complaints from researchers about workplaces

IN THE MAY 1987 issue of *Research & Development* we asked what you thought about the laboratory environment in which you work. In general, most respondents seem to be rather pleased with their research lab facilities, with 57% rating their workplaces at least good and 58% considering their immediate work environment to be pleasant. Results of the survey follow:

1. *Is your immediate laboratory environment a pleasant place to work?*
   a. Yes . . . 58% b. No . . . 22%
   c. Indifferent 21
2. *Do you have adequate benchtop space on which to do your work?*
   a. Yes . . . 59% b. No . . . 41%
3. *Does your lab bench/work area have adequate storage space?*
   a. Yes . . . 50% b. No . . . 50%
4. *Do you have an office area separate from, but in close proximity to, your work area?*
   a. Yes . . . 73% b. No . . . 27%
5. *Is your lab equipped with adequate safety equipment,* i.e., *eyewash station, fire extinguishers, etc.?*
   a. Yes . . . 72% b. No . . . 21%
6. *Is the lighting in your work area sufficient for most of the jobs you do?*
   a. Yes . . . 92% b. No . . . 8%
7. *Does the HVAC system keep you comfortable?*
   a. Yes . . . 26% b. No . . . 22%
   c. Most of the time 52
8. *Does your lab have lounge/conversation areas where you can discuss ideas away from the bustle of lab activity?*
   a. Yes . . . 41% b. No . . . 59%
9. *How many periodicals relating to the work done at your facility does the reference library subscribe to?*
   a. 0 to 5 . . . 19% c. 11 to 20 . . . 14%
   b. 6 to 10 . . . 17 d. 21 or more . . . 45
   e. We don't have a reference library 5
10. *Is the building exterior esthetically pleasing?*
    a. Yes . . . 35% b. No . . . 31%
    c. Indifferent 34
11. *Are you usually able to park within a reasonable walking distance from the building?*
    a Yes . . . 85% b. No . . . 15%
12. *How many miles do you travel to get to work?*
    a. 0 to 5 . . . . . . 37% c. 11 to 20 . . . . 24%
    b. 6 to 10 . . . . . . 23 d. 21 or more 16
13. *All things considered, how do your rate your workplace?*
    a. Excellent . . . 14% d. Adequate, but poor 13%
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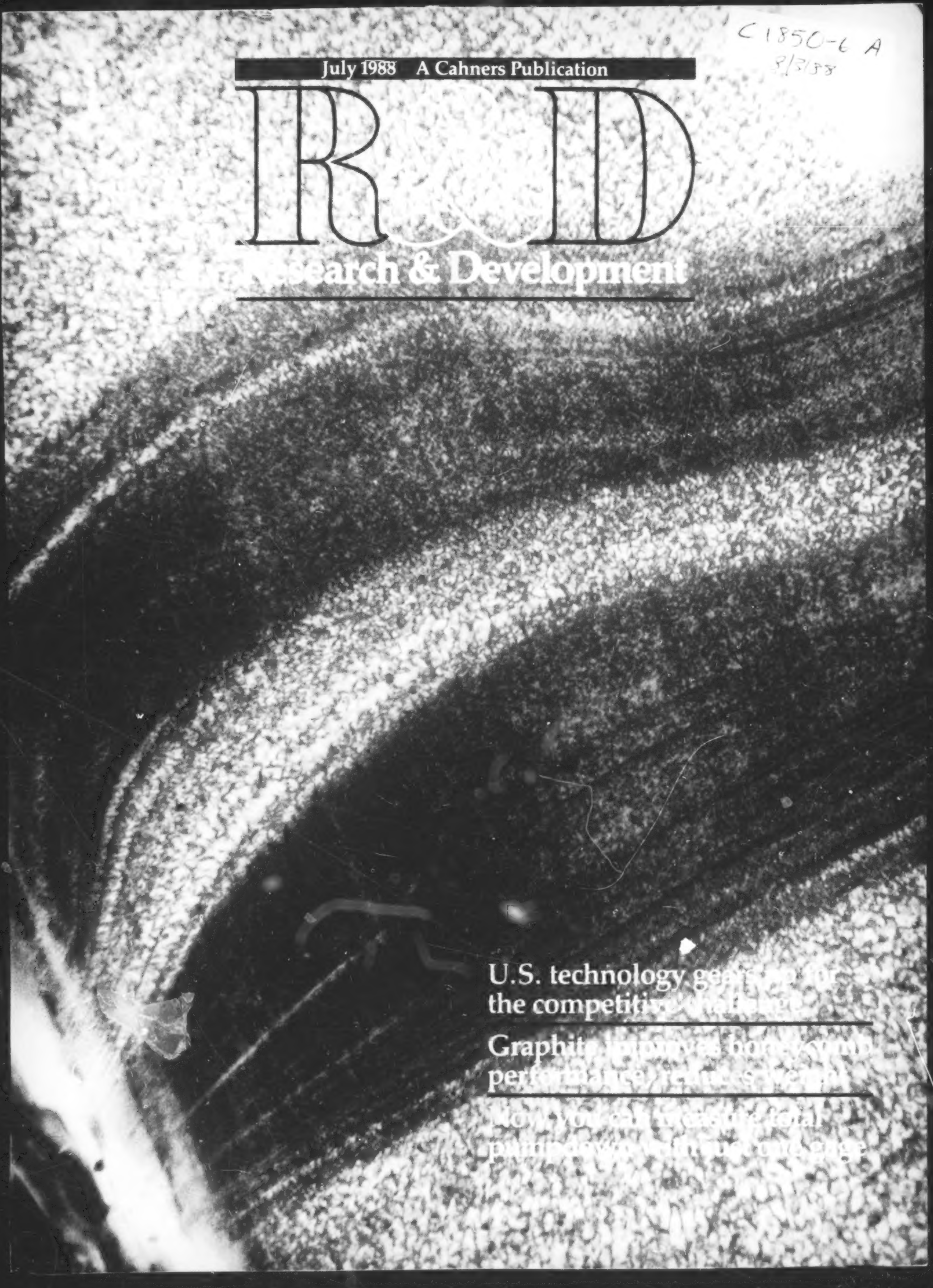

U.S. technology gears up for the competitive challenge

Graphite improves honeycomb performance, reduces weight

Now you can measure total pumpdown without ion gage

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Keep U.S. competitive, R&D 2000 leaders urge

EARLIER THIS YEAR, an *R&D* poll of 500 U.S. scientists revealed that a majority (52%) believed Japan, not the U.S., would be the leader in technology by the year 2000. This reinforced a growing concern that U.S. industry was losing its edge in the race to bring innovative products to market.

Few in business or government, however, seem ready to take a leadership role on this issue. As one Washington observer put it, "Support for R&D in Congress is a mile wide and an inch deep." We also have not had an "electrifying event"—like the launch of *Sputnik* or President Kennedy's challenge to put a man on the Moon—to rally the public to action.

Against this background, the R&D 2000 Committee was formed this past February.

R&D 2000 is a "business round table" of industry leaders dedicated to restoring America's pre-eminence in R&D and technology by the year 2000. Committee members are: Peter Browning, executive vice-president and operating officer, Continental Can Co.; Dr. Robert Fildes, president and CEO, Cetus Corp.; Dr. Joel Goldhar, professor of technology management, Illinois Institute of Technology; Dr. John Ketteringham, senior vice-president, Arthur D. Little Inc.; John Rollwagen, chairman and CEO, Cray Research; and Joseph D. Williams, chairman, Warner-Lambert Co.

The R&D 2000 Committee supports technology as the key to success in today's global economy. In the words of member Ketteringham, co-author of *Breakthroughs!*, "Technology remains the fundamental basis of economic vitality and prosperity."

While they are sanguine about America's ability to compete in technology, however, R&D 2000 members are painfully aware of the impact of increasing global competition.

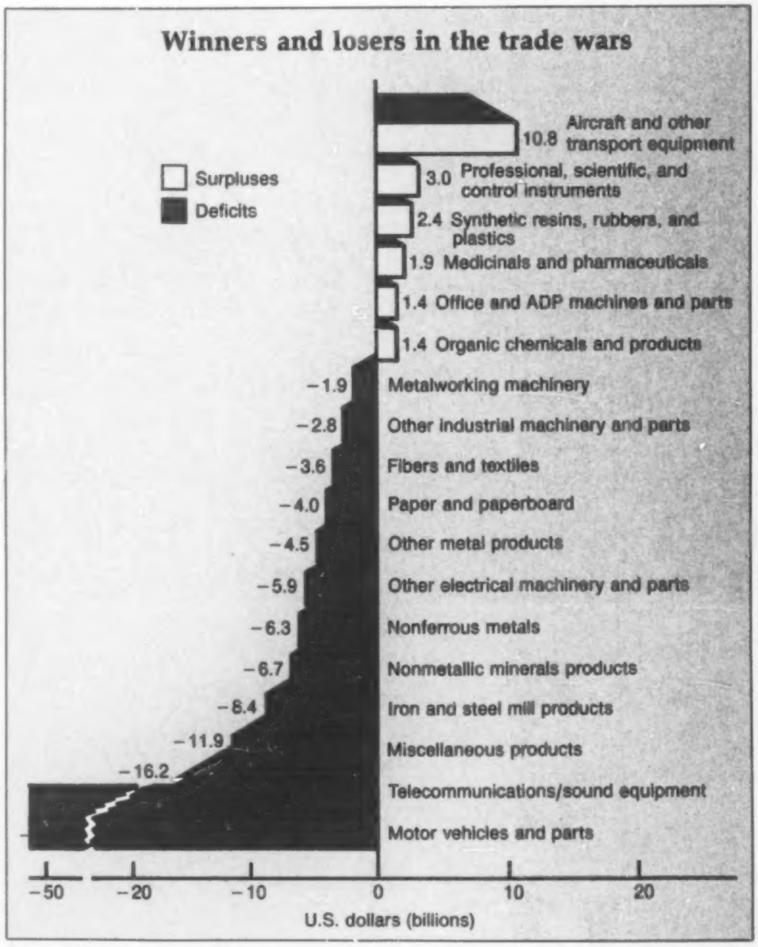
Take the case of pharmaceuticals. A decade or two ago, 80 to 90% of all new drugs were created in U.S. labs, notes R&D 2000 member Williams. Today, that figure has dropped to 60%. Warns Williams: "Relative newcomers like the Japanese are giving us and the Western Europeans a run for the money in the race to bring new drugs to the world marketplace."

In seeking to commercialize their products abroad, U.S. companies are sometimes thwarted and even barred by regulatory disparities or trade differences between countries. Says committee member Fildes, "The American market offers a level playing field to global competitors, but the reverse is not always true."

Taking a fresh approach

American companies can fight back, however, provided they consider new ways to look at their technology strategies, according to Prof. Mel Horwitch of MIT's Sloan School of Management.

Instead of wedding themselves to the model of the central R&D lab, says Horwitch, companies might distribute projects to small, decentralized research units, whether inside or outside their own walls. Instead of adopting competitive strategies with other companies, businesses might consider



Where does your industry figure in the U.S. trade imbalance? Aircraft exports, along with shipments of scientific instruments, played a positive role, but the automotive and metals sectors fueled the 1986 trade deficit of $130 billion.

***Peter Browning** of Continental Can Co., an R&D 2000 Committee member.*

***Dr. Joel Goldhar** teaches business at the Illinois Institute of Technology.*

***Dr. John Ketteringham** looks for breakthroughs at Arthur D. Little Inc.*

***John Rollwagen** holds the reins at supercomputer maker Cray Research.*

cooperative efforts, such as joint research ventures. Rather than relying on inventing everything themselves, companies might choose to buy innovations from others and then develop and market them.

Industry must remember, too, says Prof. Rosabeth Moss Kanter of Harvard Business School, that "R&D is not enough." To succeed in the global economy, industry must link R&D with commercialization, production, and marketing.

Kanter says that companies get the most payoff from their R&D investments when they:

- Scout ideas from many sources, including suppliers and employes who are not in R&D.
- Bring technical people closer to their customers.
- Include other functions—notably marketing—on the R&D team.

The innovation process is enhanced, says Kanter, when there are "close structural connections between potential innovators and users, between functions and departments, between the R&D project and the units that will move the model into production and use."

U.S. industry has lost substantial market share to foreign competitors not only because of declines in new product development, but also due to a slippage in quality. Nowhere has this concern been more apparent than in the automotive industry.

U.S. auto companies are, however, tackling the problem. At Ford Motor Co., says vice-president of research John P. McTague, "Quality is defined by our customers." Ford's Alpha Project, for example, is designed to bring employes and suppliers together to unleash new ideas. The company also has established a $75 million "Factory of the Future" fund for piloting new manufacturing technologies. One outcome: a fully integrated, flexible machining center designed by the engine division.

Slipping new-product innovation, declining quality control, increasing global market competition—these are among the issues confronting the R&D 2000 Committee. What about the response?

An aggressive agenda

Over the next year, the R&D 2000 Committee will be seeking ways to contribute business-oriented solutions to these problems. Included among its planned activities:

- Publication of a newsletter to a select list of CEOs, industry leaders, and government officials.
- Creation of an "R&D index" to measure R&D activity by U.S. industry.
- Formation of liaisons with such groups as the Council on Competitiveness and the Council on Research and Technology (CORETECH).
- Co-sponsorship of a national technology conference (see companion story).

But these are only pieces of a larger set of national concerns. Take the issue of technical and scientific education. Certainly the need for highly qualified scientists and engineers will not diminish by year 2000. But as R&D 2000 member Rollwagen says, "What does not appear as certain is whether enough people will be interested and educated to take full advantage of the opportunity.

"The most important thing we can

***Dr. Robert Fildes** heads Cetus Corp., a California-based biotechnology firm.*

***Joseph D. Williams**, a pharmacist, chairs drugmaker Warner-Lambert Co.*

(Continued from page 16)

do," says Rollwagen, "is to promote education in the sciences and mathematics in all our schools, from elementary to postgraduate. The more people are comfortable with using the tools available today, the faster scientific discovery can progress."

Besides education, there are more-immediate issues, including:

- Consistently funding basic research, so that the U.S. does not lose its edge in that department;
- Enhancing tax and other financial incentives that promote R&D;
- Removing inefficiencies caused by government controls and legislation, especially in such key agencies as the U.S. Patent & Trademark Office;
- Providing fair treatment for U.S. companies in foreign markets.

The question remains: Will U.S. industry face up to the challenge of technological competitiveness? Some fear American business leadership might remain smug about the problem. "The biggest threat to us is that our industries, our scientists, and our technologists will wake up too late" to respond to changes in global R&D competitiveness, warns Dr. William R. Graham, science adviser to the President.

For their part, the R&D 2000 Committee members are optimistic about the nation's future. Reflecting the group's consensus, Ketteringham says that America's "Golden Age of Technology" is far from dead. "Technological breakthroughs beget additional technological breakthroughs," he says.

"Knowledge itself increases as new technological discoveries facilitate its acquisition. Progress in one generates progress in the other." ☐

R&D 2000 to co-sponsor technology conference

ANY STRATEGY to enhance U.S. competitiveness in global trade must find ways in which the nation's basic industries—steel, plastics, paper and pulp, automotive, etc.—can use technological advancements to reduce costs and improve productivity.

To help find solutions, the R&D 2000 Committee will co-sponsor a day-long national conference on "Traditional Industries—Innovative Research Approaches," Tuesday, September 27, in Chicago.

"In the Midwest, as on the coasts, we have research and development leading to the creation of new companies based on new products," says conference chairman Walter Massey, president of the American Assn. for the Advancement of Science (AAAS).

The difference is that in the Midwest "you have the application of *new* technologies to the traditional manufacturing backbone industries," says Massey, vice president for research and for Argonne National Laboratory at Univ. of Chicago.

The program, co-sponsored by the AAAS, is directed at industry executives, R&D managers, academic researchers, and government lab administrators.

The opening session will examine the industrial economy of the Midwest and explore new forms of collaboration that are developing among industrial firms, universities, private labs, and Federal facilities. These "linkages" include incubator facilities, venture capital funds, research parks, and government commissions.

The central part of the day will be devoted to a set of workshop sessions, each of which will examine a real-world case of collaboration between industry and university, government, or independent research facilities. The workshops will be run twice, so that participants will be able to attend two different presentations.

The afternoon session will consider lessons learned from experiences in collaboration among the industrial, academic, and independent or Federal laboratory partners. A representative from industry will guide academicians and government lab officials on how to work with the private sector, while a public-sector speaker will advise industry executives on how to work with academia and government labs.

Dr. John Ketteringham, senior vice president of Arthur D. Little Inc. and author of *Breakthroughs!*, will close the day with a talk on "What to Do Next: Guidance for Policymakers."

Registration is $120 per person in advance, $135 at the door. Special room rates at the Hotel Nikko, 320 N. Dearborn, Chicago, are available.

For more information, contact Dr. Albert Teich, AAAS, 1333 H St. NW, Washington, DC 20005, 202/326-6600; or Rob Cassidy, R&D 2000, 312/390-2771. ☐

Analytical instruments: slowdown in growth

SHIPMENTS of analytical instruments will grow 7.4% a year through 1995, a marked downturn from the 11.5% annual growth recorded from 1977 to 1986. By the mid-1990s, the analytical instruments market will reach $4.3 billion.

Those are the major findings of a recent study by the Freedonia Group, a Cleveland, OH, research firm. The report cites cutbacks in both Federal and private-sector R&D spending as the reason for the decline.

The strongest long-term growth opportunities for analytical instrument makers over the next decade: pharmaceuticals, biomedical research, and environmental science. Spectroscopy instruments and separations systems will each have about $1.7 million in sales by 1995.

The analytical instruments market in the metals, energy, and semiconductor industries will decline over the short term due to depressed conditions in those sectors.

For more information, **circle 850** on the Reader Service card. ☐

Engineers tackle specialty certification

ENGINEERS recently took a small step toward greater professionalism, when 130 engineers from 23 membership societies held the first conference on specialty certification.

"It's something that has been brewing for a number of years, and it's just happening now," said Arthur Schwartz, general counsel for the National Society of Professional Engineers.

A few specialty societies, including the American Academy of Environmental Engineers, the Society of Manufacturing Engineers, and the American Society of Safety Engineers, already have certification programs, said AAEE past president Louis Guy.

"The problem is that the professional engineering license does not indicate whether the person is qualified in any specific branch of engineering," said Guy.

Individual societies now must decide whether to require certification.

"It has taken the medical profession close to 100 years to get where it is in certification, and it's going to take engineering a long time to grapple with the issue," said the NSPE's Schwartz. **R&D**

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Research & Development

New polypeptides respond to chemical potential changes

Use ion mobility spectrometry for detection in low ppb

Now, vacuum pumping system gives $6 \times 10^{[illegible]}$ torr oil free

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Look beyond the lab for sources of innovation

ERIC VON HIPPEL has a message for U.S. manufacturers: Don't rely solely on your in-house research labs to come up with product innovations. Open your eyes, says von Hippel, to sources of innovation you may never have dreamed of—your suppliers, your sales staff, your customers, even your competitors.

Von Hippel, a professor of technology management at MIT's Sloan School of Management, argues in a new book, *The Sources of Innovation* (Oxford University Press), that manufacturers too often assume—incorrectly, as it happens—that product innovations must be developed by industry. In doing so, they may mismanage their R&D efforts and lose their competitive edge.

"You have no hope of managing the innovation process well unless you know what the source of innovation is," he told *R&D* in a recent interview at his Boston apartment.

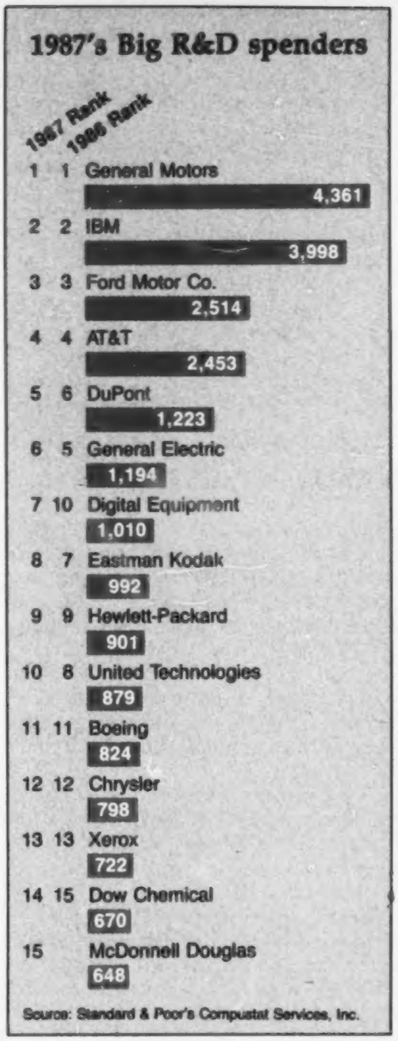
After more than a decade of research and personal experience as cofounder of a high-tech firm, von Hippel has found that the sources of innovation vary from industry to industry.

In the plastics field, for example, he has found that 9 of 10 new products are still developed by manufacturers. But in scientific instruments, three out of four innovations are developed by users. And in the manufacture of wire termination equipment, more than half the new ideas come from suppliers.

"I got interested in this problem around 1975," says von Hippel. "I kept seeing stuff coming out of R&D labs, and it worked, but I kept wondering if anybody needed it."

So he began a systematic study of user needs, starting with the analytical instruments field. To his own surprise, he found that customers not only knew what they needed but had found ways to adapt the manufacturers' equipment to meet their needs. In fact, nearly four out of five product innovations were being developed by customers—an unusually strong pattern, according to von Hippel.

Von Hippel tried to come up with a theory to account for these huge differences between user innovation and manufacturer innovation in the scientific instruments field. His answer: "economic rents," which he defines as "the extra profit you get for being an innovator."



Source: Standard & Poor's Compustat Services, Inc.

As in 1986, General Motors, IBM, Ford Motor Co., and AT&T topped the Business Week *list of R&D spenders among U.S. industrial companies. A record $54.3 billion was spent by 915 companies in 1987—more than in 1986, but less than 4% when adjusted for inflation.*

In simple terms, he found that users of scientific instruments were finding it profitable to spend their time fiddling with the equipment in order to make it work more efficiently and economically.

At this point in his research, von Hippel had a new problem to address: How could manufacturers of scientific instruments manage the process of innovation and capture the economic rents—those extra profits attributable to innovation—for themselves, rather than letting their customers keep all the benefits? Or, as he puts it, "How could you manipulate the incentives?"

Von Hippel hit pay dirt in the field of automated clinical chemistry analyzers, where three companies—Technicon, Abbott, and DuPont—were competing. Von Hippel noticed that there was an important design difference between analyzers made by Technicon and Abbott and those made by DuPont.

The first two had an "open architecture," with the functional modules connected by plastic tubing and the reagents placed in bulk reservoirs and metered into the system as needed. DuPont had a closed system. "You couldn't get at the inner workings, and the reagents came in factory-sealed test packs," says von Hippel.

Referring to the Technicon analyzer, von Hippel says, "The lab people would get in there and rip out the tubing and rig it all up to do tests it wasn't originally designed to do. Then they'd start messing with the reagents." Because the DuPont system was harder to customize, lab workers couldn't fiddle with it—and few innovations resulted.

Technicon went one step further, von Hippel notes. It sponsored a journal in which it published descriptions of the innovations—much as computer "user groups" share information through electronic bulletin boards. That gave customers an incentive to reveal the changes they had made to the equipment—innovations the company was then able to incorporate into the product.

DuPont had to bear the cost of new-product innovation alone, while Technicon was able to get its customers to share a portion of the expense.

The MIT professor also found that identifying what he calls "lead users" of a product or process can be crucial

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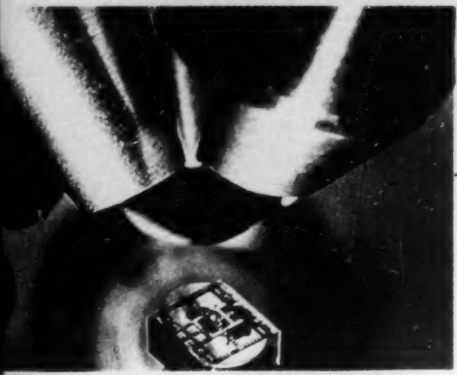

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***Vacuum chamber** of "SIMSLAB" with sample in place for analysis leads readers to page 105 and our preview of the upcoming 1988 AVS symposium and exhibition. Photo courtesy VG Ionex Ltd.*

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Nation's CEOs say U.S. may lose its R&D lead

THE UNITED STATES, while currently leading the world in research and development, is losing ground to other nations and may no longer be the world's technology leader by the year 2000.

But instead of stepping up their R&D efforts to combat this decline, U.S. corporations likely will reduce the rate of growth in their research activities over the next three years, preferring to take short-term profits over long-term gains.

Those are among the major findings of an *R&D* magazine opinion poll of chief executive officers at the nation's 476 largest industrial companies. Some of the study's findings reinforce those of an *R&D* survey of scientists conducted this past February.

At the same time, the new survey points out significant differences between how research scientists and industrial executives view U.S. technological competitiveness.

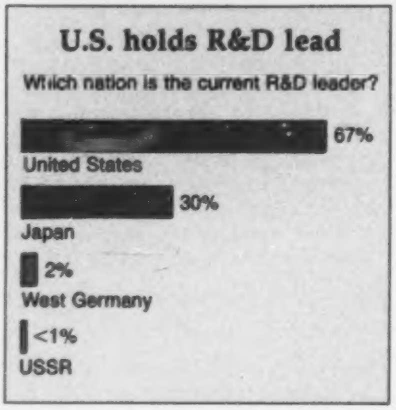
The CEO mail survey, conducted in June and July, resulted in a 26% response rate, considered by statisticians to be projectable to the universe of 476 companies at the 95% confidence level, with an error of ±10%.

A gradual decline

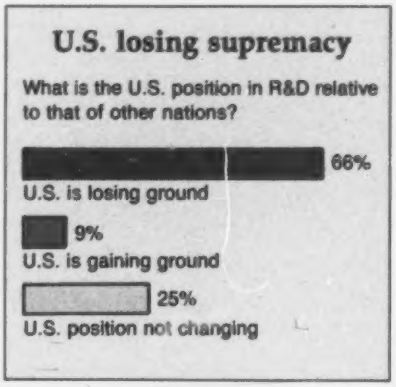
Most of the nation's top industrial CEOs (67%) perceive the U.S. to be the current technological leader in the world. Another 30% see Japan as being ahead of the U.S., with a smattering of support for West Germany (2%) and the USSR (less than 1%).

This view contrasts sharply with that of the 500 scientists surveyed earlier by *R&D*. In that study, the U.S. and Japan were seen by the scientific community as locked in a virtual tie, with 48% of the scientists stating the U.S. was ahead, compared to 46% who said Japan was leading. "Perhaps scientists and researchers, being closer to the R&D situation, are more aware of the technology gap," said *R&D* publisher Timothy M. Kelly.

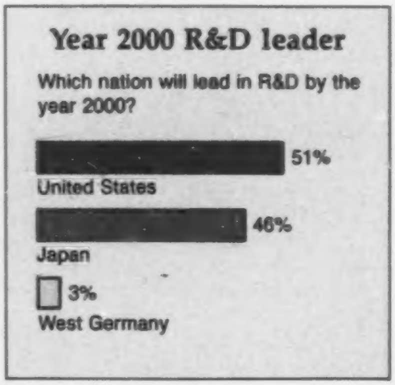
While they are more sanguine than scientists about the U.S.'s current status, a greater proportion of CEOs (66%) said they believe the U.S. is losing ground in technology to other developed nations, compared to 49% of scientists who said U.S. leadership is slipping.



Two thirds of CEOs in the R&D *poll say the U.S. leads the world in technology.*



Nearly two out of three CEOs say the U.S. is losing ground in R&D to others.



Most CEOs foresee the U.S. and Japan neck-and-neck in R&D by the year 2000.

Only 9% of CEOs said the U.S. is gaining ground against other countries, *vs* 14% of scientists surveyed. A fourth of the CEOs feel that the U.S. position is not changing relative to that of other nations, compared to a third of scientists.

Too close to call

Corporate executives predict that by the end of the century the U.S. will still be on top of the world in technology, but only by a slim margin, 51% *vs* 47% for Japan. The results are so close that it is impossible to say, from the study alone, which nation more CEOs believe will be the leader.

In the survey of scientists, however, the response was more clear-cut. By the year 2000, Japan will be the leader, according to 52% of scientists polled, compared to 38% who said the U.S. will retain that position.

"There may be slight differences between the responses of the two groups, with the CEOs a little more optimistic about the U.S. situation today," said Kelly. "But the trend is obvious. Both CEOs and scientists see the U.S. losing the lead, and Japan moving up. That's not a good sign."

Research and development plays a strategic role in 9 of 10 industrial companies, according to the survey. A majority of CEOs (56%) said R&D is "very important" to the strategic planning process in their companies, with another 34% saying it was "somewhat important."

The majority of U.S. industrial companies seems to be backing that philosophy with action. Almost two thirds of CEOs responding (65%) report an increase in R&D activity at their companies from 1985 to 1987. Only 10% tell of a decline. A fourth say their R&D activity has stayed about the same.

Looking ahead to the next three years, a smaller proportion of CEOs, about 59%, predict that R&D activity at their companies will increase, while 34% said that it will stay about the same. Although only 3% said that R&D at their companies will decline, another 4% are not sure where it will be going in the short term.

But, when asked to give some measure of the change in R&D activity for both the previous and coming three-year periods, CEOs indicated a likely reduction in the rate of growth of R&D activity in the near future.

From 1985 to 1987, the average increase for all industrial firms was estimated at between 10 and 22%, with an average increase of nearly 16% for the three-year period. Asked to predict the level of R&D activity over the next three years, however, CEOs said the level will increase between 7 and 15%, averaging only about 11%.

"Based on this forecast, we probably will be facing a relative decline in the growth of industrial R&D activity, especially when you consider the effect of inflation," said Kelly.

To get further insight into the thinking behind these plans, the CEOs were asked their reactions to this statement: "U.S. companies generally have a short-term view of research and development, sacrificing long-term gains for short-term profits."

More than three fourths of all respondents agree (60%) or agree strongly (16%) with that statement. Only 4% disagree strongly with it, while another 19% merely disagree.

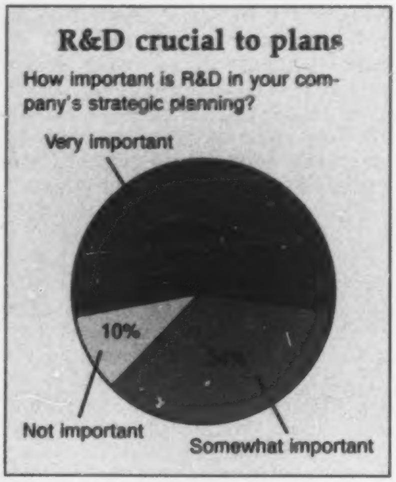
Intense pressure

"Even though we didn't ask the CEOs if this was the case at their own companies, it's apparent that executives of the nation's top industrial companies are under intense pressure to produce immediate results to please shareholders," said Kelly. "The need to boost stock prices and ward off takeover attempts apparently is causing them to trim R&D spending."

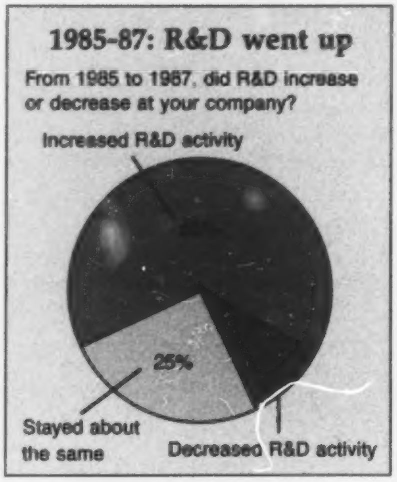
As to *how* research and development should be done, there is virtually no consensus among U.S. industrial firms. Roughly equal percentages of U.S. companies are further centralizing (18%) or decentralizing (20%) their R&D efforts. Among firms that say they are "staying about the same," 33% are "mostly centralized" and 30% are "mostly decentralized."

"There doesn't seem to be any dominant school of thinking on this," said Kelly. "Apparently it varies from company to company and from industry to industry."

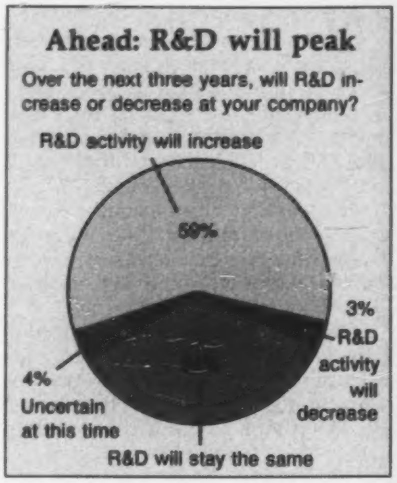
Based on the overall findings of the survey, most CEOs probably would agree with the respondent who wrote that, from a technological standpoint, "we are losing the edge." Another CEO clarified that point by saying, "The U.S. suffers from a deficiency



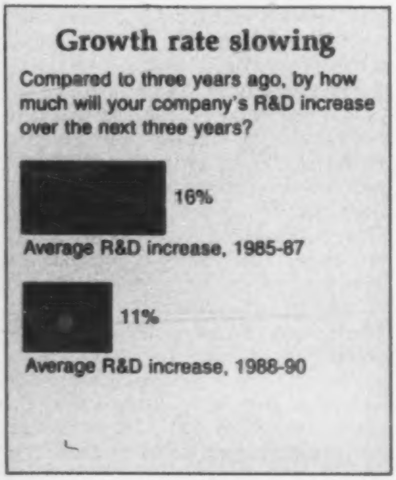
More than 90% of CEOs say R&D plays a role in their corporate plans.



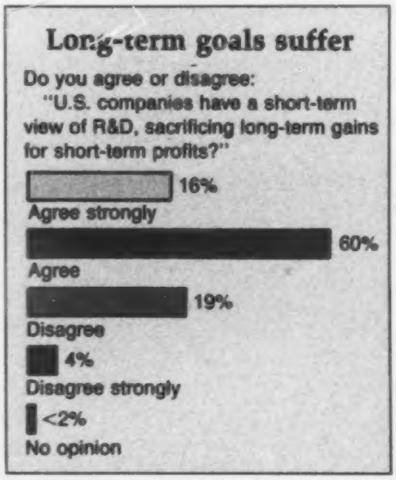
About two thirds of CEOs say their R&D had increased from 1985 to 1987.



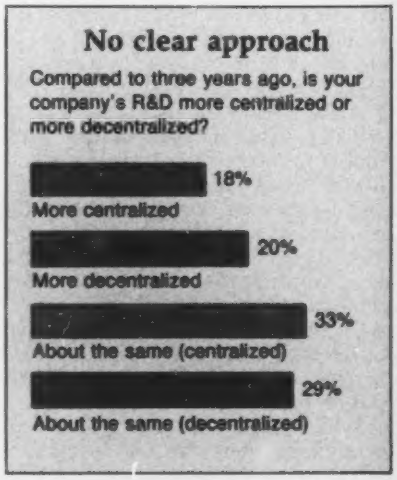
Fewer CEOs foresee their R&D activity increasing in the near future.



Growth in R&D activity will fall off in the next three years, CEOs predict.



Most CEOs say U.S. companies sacrifice long-term for short-term gains.



U.S. companies use both centralized and decentralized R&D, CEOs say.

in development rather than in basic research."

Yet there were some who, despite the pessimistic tone of the findings, offer a positive view of the future. "The U.S. lost some, but not all, of its previous advantage in R&D and now is awakened and starting to recover," said one CEO.

Added another chief executive, "My optimistic response presumes that this nation—government, industry, and academia—will rise to the challenge of reversing current negative trends in our own competitiveness." ☐

Can Intel's Noyce get Sematech rolling?

FROM SILICON VALLEY to Boston's high-tech corridor, the semiconductor business in August breathed a sigh of relief with the announcement that Sematech, the industry's research group, had a CEO.

And not just any CEO, but Robert N. Noyce, vice chairman and cofounder of Intel Corp., co-inventor of the integrated circuit, and one of the most highly respected people in the field.

As Sematech founder Charles E. Sporck, president of National Semiconductor Corp., put it, "I'm ecstatic. The ideal guy with the greatest stature in the industry is head of Sematech."

The appointment of Noyce, 60, and IBM executive Paul P. Castrucci, 54, as chief operating officer came after an exhaustive year-long search by Sporck, Noyce, and W.J. Sanders III, chairman of Advanced Micro Devices Inc. More than 200 applicants were interviewed.

"The people who wanted the job were not acceptable, and the people who were acceptable were happy where they were," Noyce told *R&D* in a phone interview. "It was like the Groucho Marx line—'I wouldn't join any club that would have me as a member.' We were aiming very high, and these people were right in the middle of their career development, on the fast track in their own companies, and they wanted to stay there."

At one point in its search, the committee almost snared Robert B. Palmer, manager of semiconductor operations for Digital Equipment Corp., and Gilbert F. Amelio, then president of Rockwell Intl.'s semiconductor program. But each of them turned the committee down when their companies made counteroffers.

Noyce said that he and Castrucci are "in a very different position, because we're coming to the end of our careers with our companies, and we're in much more of a position of not having to worry about future career moves." Both executives said they intend to relocate to Austin, TX, headquarters of Sematech. Castrucci will leave IBM, but Noyce will keep his title at Intel.

Tough job ahead

Now that the leadership question is settled, Noyce said his top priority will be to get full Federal funding for Sematech's second-year budget. Congress approved $100 million for the program last year, an amount the House has approved for the coming year as well. But the Senate appropriation calls for only $45 million.

"It would slow us down if we don't get the full amount, but we feel confident that we'll get it," said Noyce. "We believe we'll be able to correct the difference in funding in the conference committee, or it could be funded as a continuing resolution."

The rest of Sematech's $250-million annual budget comes from its 14 member corporations—IBM, Intel, DEC, AT&T, Texas Instruments, Motorola, National Semiconductor, Harris Corp., Rockwell Intl., NCR, LSI Logic Corp., Micron Technology, Advanced Micro Devices, and Hewlett-Packard.

Each company contributes 1% of sales, with a minimum of $1 million. The maximum for any company is 15% of the total corporate contribution, to prevent domination by a single corporation.

The executive team's second priority is, in Castrucci's terms, to make Sematech "the West Point of manufacturing" by attracting the best and the brightest in the industry to Austin. The staff will be beefed up from the current 135 to about 250 by year-end, then doubled again in 1989.

Sematech CEO Noyce: Will he be able to turn the semiconductor industry around?

"We're trying to shoot pretty high" in the quality of hires, said Noyce.

The real challenge will be to develop new manufacturing processes for the semiconductor industry—to, in Noyce's words, "reverse the downward trend and make this the premier industry in the world."

When Sematech was being formed, Noyce's company, Intel, wanted the consortium to actually manufacture chips in competition with the Japanese—a work program that was rejected by the group's architects.

The five-year plan is for Sematech to develop advanced semiconductor manufacturing processes, materials, and equipment at the consortium's 300,000-ft^2 facility, which should be ready for occupancy later this year.

One research option will be to come up with ways to increase productivity by making chips on 8-in. wafers instead of the 5-in. ones currently used and to find manufacturing techniques to cut the size of chips in half.

Once these innovations have been proven, they will be transferred to the consortium's members for use in commercial applications.

Need for cooperation

An industry-wide approach is necessary, said Noyce, to reverse the trend begun by the Japanese in the mid-1970s, when they launched a $400-million government-sponsored R&D program targeting very large scale integration (VLSI) semiconductor technology—an initiative that allowed the Japanese to go on to dominate the memory-chip market.

"As long as we were competing against the Japanese as individual companies, we were beating them, but when they were able to work together, they were able to change that situation," said Noyce. "They got their companies together then for the same reason we're doing it now, because they had been beaten."

Noyce feels that Sematech can rise to the challenge, even if some critics of the program label it a huge gamble. "I don't think it's a crap shoot," he said. "There is a problem in that we're putting people together from 14 different corporate cultures, and things are going to have to settle down before we have a Sematech culture."

But, said Noyce, "even if we don't succeed in achieving our full objectives, Sematech will still have a big effect on the industry."

—*Robert Cassidy*

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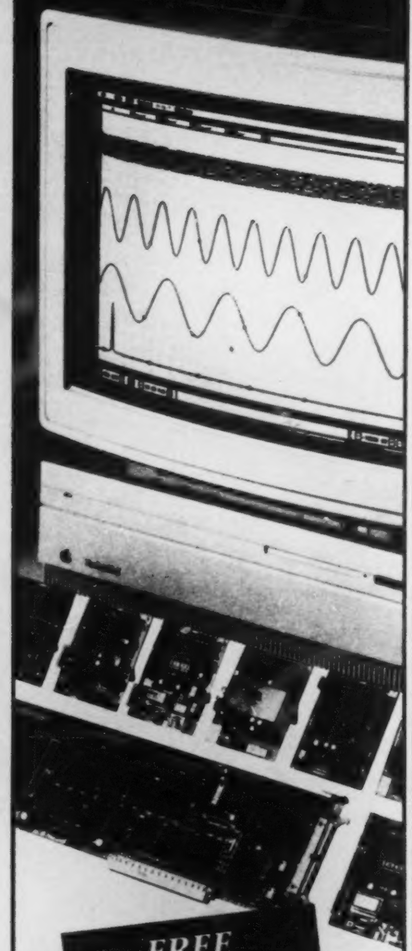

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